

THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

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Chronicle and Comment

Joint Tractor Meeting

IN this issue will be found papers by William Parrish, of the International Harvester Corporation of America, Inc., and T. Warren Allen, of the Bureau of Public Roads, dealing with the industrial application of tractors. These papers are to be presented at the Joint Tractor Meeting of the American Society of Agricultural Engineers and this Society, which is to be held in Chicago on Dec. 1 to 3. The January, 1927, issue of THE JOURNAL will carry the complete story of the meeting.

Automotive Transportation

THAT the holding of automotive transportation meetings is the direct responsibility of the Society was demonstrated conclusively at the Transportation and Service Meeting in Boston, Nov. 16, 17 and 18.

Men associated with all phases of automotive and allied engineering work mingled freely with a refreshing spirit, exchanging ideas with associates, competitors and executives whose past problems have been connected with the operation of steam and electric railways, but whose present major problem is the economical adaptation of a new tool, *automotive transportation*.

Getting the older transportation organizations to recognize the possibilities of the newer type of transportation has been a problem. To convince those in the new field that they should curb undue enthusiasm and recognize the real merits of rail units has also been a problem for automotive units. The Boston meeting demonstrated that a common meeting-ground has been found. Potential power was stored that augurs well for future transportation meetings.

A problem of National as well as local importance remains to be analyzed and the fundamentals involved established. The engineering fraternity will play an important part in the solution. No group of men is more competent to find the answer than that gathered in Boston, assisted and guided by the cooperative spirit of the Society.

The Boston Transportation and Service Meeting was not a local event; it was planned and fostered along National lines. The attendance clearly indicated that this was recognized. Leaders in their profession stated their difficulties; remedies were suggested in a constructive spirit.

Special thanks are due the members of the New En-

gland Section of the Society for their earnest and untiring efforts that resulted in no overlooked details marking the program. Their foresight and work were splendid. The officers of the Society and the members of the Meetings Committee keenly appreciated their assistance.

Ripplingille Heads Carnival Committee

THE plans for the 1927 Carnival, which as usual will be held at Oriole Terrace, are now taking shape under the direction of Chairman E. V. Ripplingille and the other members of the Carnival Committee. Several new features will be introduced. These will make the Carnival appeal more strongly than ever to members of the Society and their guests. The Carnival has become a red-letter annual event for those who reside in Detroit and visit that manufacturing center of the industry at the time of Annual Meetings of the Society. The 1927 Carnival will be held on the evening of Friday, Jan. 28.

Bouquets to John Warner

PRIOR to his departure to take up work with the Studebaker Corporation of America, John Warner, formerly Manager of the Meetings and Sections Department of the Society, was given a luncheon at which a suitably engraved watch was presented to him by members of the Society office staff. At Eastwood Inn, near Detroit, on Nov. 22, an enthusiastic and very enjoyable dinner was tendered him and a token of appreciation of many members, in the form of a clock, duly delivered in recognition of good service. Apparently, the reliable and admired John will be thoroughly "clocked" from now on.

Index to Vol. XIX

OMITTING the Index to Vol. XVIII, covering the numbers from January to June, inclusive, from the last-named issue of THE JOURNAL enabled the members to receive the news account of the Semi-Annual Meeting practically at the same time as the trade papers containing the story arrived on their desks. Following this precedent, the Index to Vol. XIX, of which this, the December, number is the last, has been omitted. This index will be printed as a separate pamphlet and mailed as Section 2 of the January, 1927, issue of THE

JOURNAL. This issue will probably be mailed to the members the last of this month.

Detroit and the Annual Meeting

BEGINNING with a technical session on Tuesday morning, Jan. 25, and ending with a session on the afternoon on Friday, Jan. 28, the professional features of the Society's Annual Meeting will be staged and discussed at the General Motors Building in Detroit. The Meetings Committee has endeavored to interpret the thought of the industry in a program covering subjects that clearly warrant attention and study. It is expected that 10 sessions will be held at which over 30 papers will be submitted. These papers, which are now being written by authorities in their respective fields of endeavor, will be available prior to the meeting. Copies will be forwarded to those desiring to study the papers in order that they can more readily take part in the discussions.

The Annual Dinner

THE night of Thursday, Jan. 13, will again find the members of the Society holding their Annual Dinner at the Hotel Astor in New York City. The Dinner Committee, under the chairmanship of H. O. K. Meister, is arranging an extremely interesting program.

The date selected for the dinner is during the week of the New York Automobile Show, which will result in New York's being temporarily the center of population of the automotive engineering as well as executive fraternity. The Society's Annual Dinner is an event of unparalleled interest during the week of the New York Automobile Show. The members may rest assured that this year the plans of the Dinner Committee will crystallize into an occasion that will equal if not excel former dinners of the Society.

The Key to the Freight Terminal Problem

THE paper presented by Bruce V. Crandall, of the *Railway Review*, at the Transportation and Service Meeting held at Boston last month not only threw considerable light on the basic considerations involved in the relation of motor-vehicle operation to transportation in general, but was very inspiring to those who are studying these matters now and particularly to men engaged in the automotive transportation field. The title of Mr. Crandall's paper was The Railroad Freight-Terminal. It is published in this issue of THE JOURNAL, on p. 601.

Mr. Crandall states that nothing is more important to the welfare of the Country as a whole than the solution of the freight terminal problem. In general, he is of the opinion that terminals should be located in the outskirts of cities and that delivery to destination of freight from these terminals inward to cities should be made by motor-vehicle. He strongly advises planning for conditions as they are expected to be 50 years hence. He is firmly of the opinion that this whole subject is very much the business of the automotive men; in a

word, that the motor-truck is the key to the whole situation. Plainly, the duty of many members of the Society is to give attention to the conditions surrounding rail operations, including of course the natural scope, the limitations and the necessary complements of the older form of transportation. Naturally, the problems that Mr. Crandall outlines are not new to many railroad men. Nevertheless, what is said in the paper is timely and can be perused by the members with much benefit.

Bureau of Standards Yearbook

THE Bureau of Standards has in preparation a companion volume to the Commerce Yearbook issued by the Department of Commerce that will describe the general standardization activities of the several agencies of the Federal Government, States and municipalities and technical and industrial societies and associations. Reference will also be made to organized effort for international standardization and to foreign national standardizing bodies and their relation to the standardization movement in America. The Society has furnished the Bureau with information regarding its history, organization and procedure, as well as its more important projects and accomplishment in standardization. It is expected that the Yearbook will be ready for distribution by the end of this year or soon thereafter.

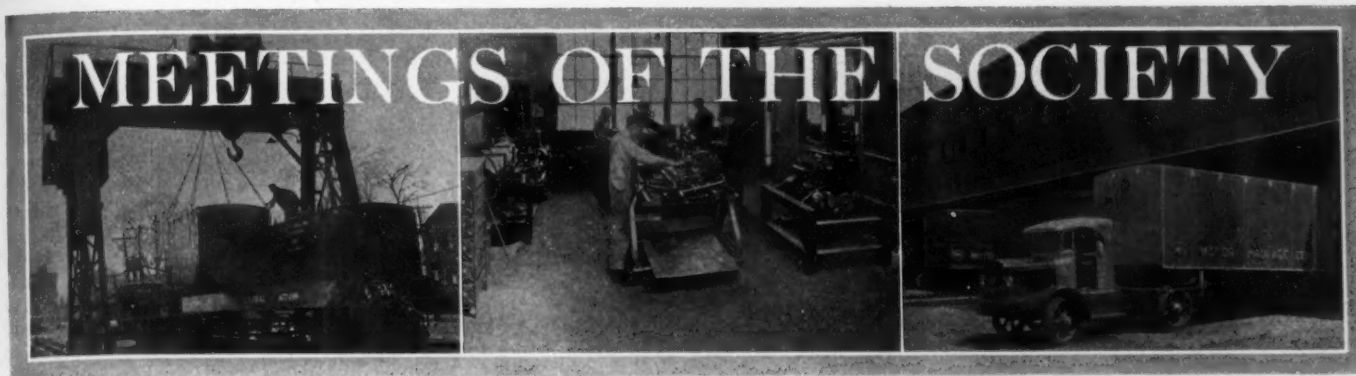
Sources of Supply for S.A.E. Standard Parts

THE September issue of the S.A.E. HANDBOOK contained, among other features, an Index to Advertisers' Products in which were listed those advertisers whose products conform to S.A.E. Specifications. The Council has authorized the extension of this classified directory in the March, 1927, issue, to include under a similar listing all manufacturers of automotive parts and materials whose products are made in accordance with our standards regardless of whether or not they are advertisers. On such parts and materials as may be logically considered stock items, an attempt will be made to indicate those firms carrying stock. It is felt that this directory will cause an extended familiarity with S.A.E. Standards and the work of the Standards Department, and it is believed that many manufacturers will attempt to adjust their production to these standards to obtain the benefits of directory listing.

Favorable comments received from various purchasing departments regarding the existing directory indicate that the proposed extension of the list will be of still greater value to such departments and increase substantially the acceptance of S.A.E. Standards in all work, particularly new design.

This matter is being presented with the anticipation of comments and suggestions as to names of companies falling within this classification that cannot be obtained through ordinary channels. It is to be understood that all companies applying for listing must certify their products. The directory list, which will be checked semi-annually, will add greatly to the usefulness of the S.A.E. HANDBOOK and the standards work as a whole.





OVER 400 ATTEND BOSTON MEETING

Attendance at Sessions, Banquet and Inspection Trip Establishes Record

The attendance at the annual Transportation and Service Meeting at the Copley-Plaza in Boston, which surpassed all records for Society Transportation Meetings, proved conclusively that, in selecting Boston for the location of the 1926 meeting, the Meetings Committee appreciated the economic importance of automotive transportation to New England. The average attendance at the technical sessions was over 200 and at the Tire Session on Thursday afternoon, the last session of the meeting, over 150 were present when A. W. Herrington, as chairman of the session, adjourned the meeting at 5 o'clock.

At the Banquet on Wednesday evening 313 members and guests were present. Over 200 visited the maintenance plant of the Standard Oil Co. and the laboratories of the Massachusetts Institute of Technology. The interest in the papers presented was manifested in the discussion that followed their presentation, adjournment of every session cutting off the discussion long before the members were ready to leave.

The attendance was representative of the several interests involved in automotive transportation, which was largely responsible for the spirited and valuable discussion that followed every paper. A list of the members and guests present is given on p. 530.

Although all the papers presented at the technical sessions could not be published in this issue of *THE JOURNAL*, a complete account of the meeting is given hereinafter in which the papers not printed in this issue are abstracted together with the complete discussion on each.

SPEED UP FREIGHT-HANDLING STUDY

Plea of Speaker in Urging Thought on Fundamentals of Transportation

Declaring that he was impatient with the progress being made in solving the question of merchandise transportation, F. I. Hardy, of the Boston & Maine Railroad, summarized the attitude at the Freight Handling Session, the earnest desire to press forward in the maze of difficulties surrounding this problem until a solution is achieved. In this first session on the morning of Nov. 16 was evidenced the farseeing, co-operative spirit that characterized the Transportation and Service Meeting. Voicing the same sentiment as Mr. Hardy, Chairman F. C. Horner, of the General Motors Corporation, urged that progress be made to take on a more rapid pace. He called for greater frankness between truck builder and prospective operator and between operator and railroad in the effort to arrive at a better understanding of their common problems and led the discussion over a wide range, from theory and fundamentals, without which, as he pointed out, no practice is possible, to the small concrete operating details, significant because indicating that the members of the audience were visualizing the subject matter of the papers in its application to their own individual activities. Motor-truck builders and operators were voluntary contributors, as a

matter of course, and in addition a number of railroads testified to their spirit of cooperation by sending representatives to participate in the discussion.

The papers delivered at the session were *The Motor-Truck's Place in Transportation*, by F. I. Hardy; *Scientific Transportation*, by W. P. Kellett, consulting engineer, which is printed in full in this issue; and *What Can the Container Do For Freight-Transportation*, by Donald W. Perin, of the Perin-Walsh Co.

Introduced as a pioneer in the application of the motor-truck to railroad requirements, Mr. Hardy first referred briefly to the experience of the Boston & Maine Railroad, the preliminary surveys of the fields thought available to the motor-truck and the actual operation of store-door delivery in Boston and Lawrence, of over-the-road trucking and of transfer transportation in the city of Boston to the extent of about 350 tons per day.

Although impatient at the rate of present progress toward the solution of the freight-handling problem, Mr. Hardy declared "I am not pessimistic on the past or on the future as to what has been accomplished and what will be accomplished." The essential for arriving at a settlement of the many questions involved, he pointed out, is to sweep away, in discussions, the petty phases of the problem, such as bodies, tires and chassis, so that the fundamentals may be readily perceived and by careful analysis to straighten out complexities. The end to be reached is that the tonnage which can best be moved on rails should be placed on rails, and that goods more suitable for carriage by motor-vehicle be assigned to trucks. In other words, each and every man interested in transportation should sell the most economical transportation.

That in the apportionment of merchandise-carrying the motor-truck will receive a share, Mr. Hardy feels cannot be seriously questioned, although he did not propose to define exactly what this share would be. He cited, in support of this conviction, the large sum of money now invested in the industry, after only a few years of existence; some \$8,000,000 in vehicles, he estimated, in addition to a much greater sum in garages and auxiliary equipment and said

Surely, this business could not have grown so rapidly and to such vast proportions unless its service in some instances was superior to any other form of transportation offered.

Railroad executives realize that the motor-truck is a factor in good transportation and in this connection Mr. Hardy said

Most railroad men feel that if the motor-truck is an enemy, it has already done about all it can ever do to them as an enemy, and, therefore, the only thing left for the trucking industry to do is to cooperate and co-ordinate with the railroads in giving a service to the public.

Upon whose shoulders depends the responsibility of deciding just what place the motor-truck shall fill? Five parties are interested in the question: the public, the shipper, the motor-truck builder, the operator, and the railroads. Transportation is too complex a problem for intelligent first thought by the public, although the public is the final judge on every subject. Transportation interests the shipper only as it affects his business, and it is, furthermore,



Donald W. Perin



W. P. Kellett

TWO OF THE FREIGHT HANDLING SESSION AUTHORS

only a small part of that business. While the motor-truck operator by his activity has helped to focus attention on the transportation problem and induced others to study it, his field, too, is too narrow to permit of contributions that would form, unaided, the basis for a comprehensive solution. These considerations led Mr. Hardy to this conclusion:

The two interests most responsible for the solution of the motor-truck's place in transportation are the motor-truck builders and the railroads.

CONTAINER SYSTEM NOW IN USE DESCRIBED

In Mr. Perin's paper the container was presented from two different angles: first as a means for accomplishing transfer of freight between railroad and motor-trucks without rehandling and second as a mechanical accessory for increasing the efficiency of both agencies. To illustrate the saving to be accomplished by the use of unit containers, three different methods of carrying shoes from a factory to a department store were compared; ordinary less-than-carload freight, inter-city motor-truck haulage and a unit-container system. After summing up the advantage to shippers, consignees and railroads claimed to result from the use of containers, Mr. Perin gave some suggestions as to their design, illustrating his remarks by pictures of a system in regular operation between Boston, Worcester and Springfield, Mass.

A fundamental requirement, he said, was that new equipment must work universally with as many different types of existing standard equipment as possible. The proper size and shape of containers can be settled only after extensive use and experimentation, but certain limits can be set. The width must not exceed 8 ft., the maximum set by the majority of States for a motor-truck with its load. If one dimension of the container is 8 ft., the other can be any even subdivision of 36 ft., the average length of freight-cars. To go below 4 ft., in the opinion of Mr. Perin, would not be advisable, as the average less-than-carload freight would not load to good advantage in such a conveyor.

Of the three methods of handling containers, by hoist or lift-off, ramp tracks and roll-off, Mr. Perin prefers the last. The roll-off method has, he said, a wider application than either of the other two and is limited chiefly by the size of the doorways through which the container must pass. Each container to be so handled is provided with swivel casters, on which it can be rolled from the motor-truck chassis onto freight-house platforms, up and down ramp floors to different levels and over skids into box cars. Such receptacles can also be carried on flat cars if cross tracks and special locking devices are provided. Several containers can be coupled together and pulled in trains along freight-house platforms by electric industrial tractors, or single containers can be carried on electric industrial lift-trucks. The containers can be rolled onto elevators and carried to any part of a building, provided the doorways are large enough.

The ease with which the receptacles with their swivel casters may be hauled is illustrated in the accompanying illustration.

This picture answered graphically a question as to whether smooth cement floors were needed for the movement of the containers.

Just how a unified system for the movement of containers could be brought into being was the final point included in Mr. Perin's paper. All of the plans suggested necessitate the creation of an organization engaged in the business of complete transportation of freight from shipper to consignee. To establish such a unified agency calls for a tremendous amount of capital and the utmost cooperation between bankers, railroad executives, government agencies, and automotive interests. Declaring that the automotive industry is ready and willing to go more than half way to meet any cooperative effort, Mr. Perin called upon bankers and railroad managers to get together to work out a solution of the problem.

ENGLAND'S FURNITURE-VAN SYSTEM RECOMMENDED

Mr. Kellett's paper dealt chiefly with a container system that he characterized as virtually a duplication of the English method of transporting furniture. It could, he said, be universally applied with advantage from haulage distances of 15 miles up. He visualized the benefits of a gradual spread of the system, from a start as a purely local movement up to nation-wide applications, as its advantages became evident. The basic appeal of the plan outlined, he said, is speed, speed with economy.

Characterizing motor-truck freight haulage in competition with the railroads as unsound, uneconomic and entirely unnecessary, he made a plea for the railroads to assume direct responsibility for the entire movement of merchandise freight from the consignor's to the consignee's door. As an instrument through which the coordination of rail and road traffic can be brought about, the container has great value, he said. The system he proposed consists of one or more standard railroad flat cars provided with trackways for the container wheels. These trackways are composed of light-stock channels laid flush with the car deck to a gage corresponding with that of the container wheels.

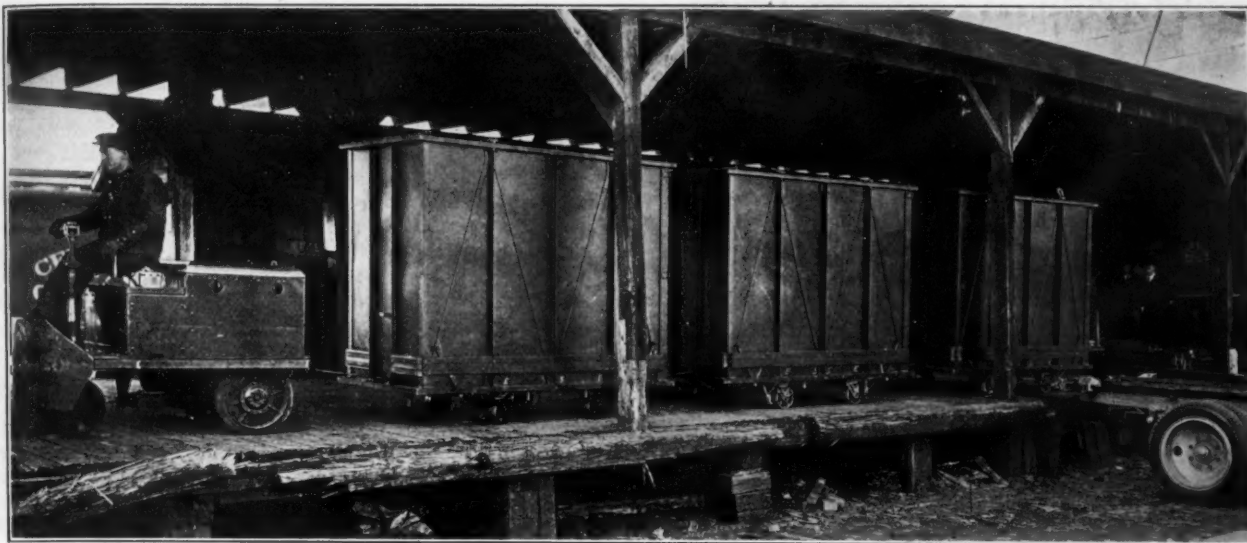
All containers are provided with four short safety chains, one at each corner, that couple them together when in place on the car. They are of the roll-off cantilever type, having four sets of small caster wheels, so that they can be moved freely in any direction. Carrying cars are equipped with devices for locking containers in place on them. Containers are provided with bumpers to lessen the uncushioned shock to which their contents are subjected.

Once the container system is adopted, railroads should, according to the suggestion outlined, enter into agreements with the express companies, to the past excellent service of which a tribute was paid. Through such arrangements, transportation would be coordinated. Express companies might be permitted to extend their field of operation to include the transportation of all less-than-carload freight shipments of 150 lb. or less.

DISCUSSION CENTERS ON THREE MAIN TOPICS

Three questions occupied a large part of the discussion. The first was, what is the status of the store-door delivery? Is this type of service really in demand? Two discussers questioned its appeal, referring to the results of a questionnaire sent out by the Merchants Association of New York City to support their conclusions. Another view was that if shippers desire store-door delivery, they can get it under present conditions in all large cities from trucking companies operating under agreements with railroads. Store-door delivery is in existence, Mr. Hardy declared; the only open question is, who will perform it?

Another point that drew forth many remarks was truck operating costs. A number of speakers expressed the conviction that little is known about motor-truck economy. The suggestion was made that following the example of the railroads a standardized accounting practice be adopted. One reason advanced for operating costs as estimated by the motor-truck builder not being sufficiently informative was, that they are based on performance carried out under the direction of experts and not of the average driver, with



CONTAINERS BEING HAULED ON STATION PLATFORMS

No Specially Prepared Surface Is Needed for the Movement of These Units, As This Illustration Proves

whom both operating and maintenance charges would be larger. Due to this and other causes, such estimates are often only 30 per cent of attainable costs, one speaker said. Another criticism was that in figuring probable profits, the capacity of trucks is greatly over-rated and the assumption is made that full loads are always carried. The cost per mile, or better still per ton-mile or per passenger-mile should be the basis of calculations instead of cost per day. In forecasting operating expenses, the type of commodity carried should be considered, according to one discussor, as it costs more to deliver some goods than others. Pointing out that we cannot know what either a truck or a man is worth in this world until after it or he is gone, a motor-truck operator stressed the necessity of having records covering the entire period of the vehicle's life instead of just 1 or 2 years. Some disagreement was registered as to whether administrative expense should be included in operating costs or figured upon separately.

Two estimates of motor-truck operating-cost were given. One fixed the figure at \$35.18 per day. The other counted on expense during standing time, with driver on the seat, of 0.0416 cents per min.; and when the vehicle was running, a wheelage cost of from 27 to 52 cents per mile, depending on the season.

A point in the study of transportation by container toward which careful thought was directed is the extent to which it can be fitted into the prevailing trend of traffic. The prevailing trend of traffic, one speaker said, is eastbound. Since the producing section is in the West, two loaded cars move east to one that moves west. The utilization of westbound empty box cars is important. However, if special equipment has to be provided to move the containers west, a charge is being injected into the cost of transportation that will have to be counted on in deciding on the economy of using containers on long-haul traffic. This speaker asked that advocates of container-systems bear in mind that a more uniform kind of equipment is needed, not a greater complexity of units.

FUNDAMENTALS TO BE STUDIED

Special Joint Committee To Establish Automotive Freight Transportation Basis

At the Freight Handling Session on the morning of Nov. 16, F. I. Hardy, of the Boston & Maine Railroad, emphasized the need of studying the economic fundamentals of auto-

motive freight transportation. He felt that if a committee were appointed consisting of 15 men, selected in equal numbers from the railroad field, the motor-truck industry and the largest motor-truck operators, and this committee were to meet behind locked doors for 3 days, they would agree on the fundamentals which would initiate a coordinated activity that would accomplish more than could be accomplished through the holding of transportation sessions over a period of 5 years.

Lack of time at the morning session prevented any action being taken on Mr. Hardy's suggestion, but at the afternoon session, F. J. Scarr, chairman of the session, appointed a committee consisting of F. I. Hardy, F. C. Horner, J. G. Lyne, R. E. Plimpton and J. F. Winchester, to prepare a resolution in line with Mr. Hardy's suggestion. This committee reported back at the close of the session, submitting the following report which on motion by M. C. Horine, duly seconded, was passed as the consensus of opinion of the meeting.

REPORT OF SPECIAL COMMITTEE

Your Committee submits the following report and respectfully suggests that it be adopted as the sense of this meeting.

There is a definite necessity for agreement on fundamentals of automotive freight transportation in its relation to other transportation facilities. It is believed that the Society of Automotive Engineers should sponsor a study of these fundamentals.

These fundamentals should be established and defined by a joint committee representing the Society of Automotive Engineers, the National Automobile Chamber of Commerce and the Railroad Motor Transport Conference. The committee should consist of three representatives of the Society of Automotive Engineers, three of the National Automobile Chamber of Commerce, and five of the Railroad Motor Transport Conference. The committee representatives of the automotive organizations should include not less than three members actively engaged in the solution of motor-transport problems.

It is requested that this resolution be transmitted to the Council of the Society of Automotive Engineers, and that it be acted upon favorably at an early date.

F. I. HARDY
F. C. HORNER
J. G. LYNE
R. E. PLIMPTON
J. F. WINCHESTER.

FREIGHT TERMINALS MUST BE MOVED

Proper Location Depends on Future Use of Motor-Truck in Transportation



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BRUCE V. CRANDALL

A cow has often been blamed for the design of the city of Boston. The statement has been frequently disputed and violently denied although not successfully disproved, and those who discredit the story have not succeeded in revealing, in any form that would take hold of the popular imagination, the identity of whoever did it if the cow did not. A counter-assertion, however, has very recently been made. In the selfsame city of Boston, on the afternoon of Nov. 16, 1926, at the Coach-Truck-Railroad Session of the Transportation and Service Meeting, a speaker said

that the horse is responsible for the industrial layout of every city in the United States. This statement, made near the close of the session, went to the root of the afternoon's discussion, as the session dealt, broadly, with the new transportation conditions that have sprung into being with the advent of the motor-vehicle, the problems that have arisen because of apparent conflicts between the newer and the older interests and the need for a rapid and proper solution of the problem of coordinating the new facilities with those already established.

NEW TOOLS, NEW PROBLEMS

F. J. Scarr, of the Pennsylvania Railroad Co., who presided, opened the session with a brief statement regarding the value of professional gatherings such as the Transportation and Service Meeting, in affording a medium through which benefit can be derived from the interchange of experience among persons engaged in similar and allied fields. Commenting on the position of the railroads in relation to the problem of motorization, Chairman Scarr read two very pertinent paragraphs from the proceedings of the Railroad Motor-Transport Conference of which A. P. Russell, the second speaker on the afternoon's program, is chairman. Because of its bearing on the topic under discussion, this material is quoted herewith.

New transportation tools have raised new transportation problems. The motor-vehicle has created new

conditions and new demands and is offering new opportunities for operating economy and efficiency. The problem of coordinating the new facilities with those already established has been much discussed. Experiments have been conducted and have given way to satisfactory solutions. The problem has constantly grown in importance until proportions have been reached that command the attention of all students of transportation.

The time has been reached when individual action must give way to concerted action. The interest of the individual carriers, as well as that of the whole transportation system, can best be served by meeting this important problem squarely. The public interest demands a correct and reasonably prompt solution.

REMOVE FREIGHT TERMINALS FROM CENTER OF CITY

Bruce V. Crandall, of *Railway Review*, in his paper entitled *The Railroad Freight-Terminal*, confined his remarks largely to the placing or locating of the railroad freight-terminal, with special reference to the situation as it exists in Chicago. Going into the question as to why railroad freight-terminals occupy their present locations, the speaker pointed out that they were placed there many years ago, when transportation problems were far different from those that prevail today and stressed the importance of meeting changed conditions, saying that economy and efficiency demand that new terminals should be planned for new locations, with a view to present needs and future requirements. The new terminals, he said, should be far removed from the center of the city. Mr. Crandall, after discussing some of the benefits that would result from the following of his plan, asserted that the automotive industry should do everything possible to solve the problem of the railroad freight-terminal because the automotive industry has in the motor-truck the largest part of the answer to this problem. The location of freight terminals of the future, he stated, will be dependent upon motor-truck operations and upon how well the automotive industry adapts its equipment to the elimination of the economic waste of down-town terminals and trap-car movements. Emphasizing the fact that a tremendous field awaits the automotive industry in helping the railroads and electric railways in solving the problems of transportation, the author voiced the view that until all forms of transportation are coordinated, with a consequent lessening of economic waste and the increasing of efficiency, the public pays the bills and the brakes are dragging on the wheels of civilization.

Mr. Crandall's paper is printed elsewhere in this issue of *THE JOURNAL*.

SHOULD RAILROADS CONTROL HIGHWAY TRANSPORTATION?

Arthur P. Russell, of the New York, New Haven & Hartford Railroad Co., announced that he would tell in a general way the story of the New Haven's highway operation, without adhering to the formal paper on that subject which had been prepared for the occasion and which is printed in this issue of *THE JOURNAL*. Mr. Russell discussed the various causes contributing to the situation that has compelled and is now compelling the railroads of the Country to look carefully into the question of retrieving some, if not all, of the loss that has resulted from the increased use of the highways for passenger travel and freight movement. A study of this situation, he said, led to the organizing, in June, 1925, of the New England Transportation Co., which is now operating a substantial mileage on the highways in southeastern New England; this company was formed not only to supplement the rail service but, where necessary, to take its place either in whole or in part, and in addition to endeavor to find a way to retrieve the revenues that were being lost in the passenger traffic between the large interstate cities.

Expressing his opinion that the highway business should be controlled by the railroads and the street railways of the Country, Mr. Russell stated that the operation of the New England Transportation Co. in the last 15 months has convinced those who have been responsible for it of the



G. Lloyd Wilson



A. P. Russell

AUTHORS OF TWO PAPERS PRESENTED AT THE COACH-TRUCK-RAILROAD SESSION

necessity of coordinating the rail and the highway transportation. Quoting figures to show what effect is had upon an interurban electric railway if a competing motorcoach service parallels it and comparing the figures with those that result if the interurban electric railway installs its own motorcoach services as an auxiliary, the speaker showed that the latter procedure is more profitable to the electric railway company and expressed his belief that the service furnished to the public is at the same time improved.

WHAT ABOUT BAGGAGE, MAIL AND EXPRESS?

In reply to a question from R. E. Plimpton, of *Bus Transportation*, Mr. Russell stated that, in cases where the motorcoach has been completely substituted for the steam train, a demand exists for a supplementary service that will take care of baggage, mail and light express. Baggage compartment coaches are used to take care of the baggage; on some lines, a truck is maintained for the purpose of handling the express and the mail. When the rail service is supplanted, to give the public the customary service in connection with baggage, express and mail is still necessary; when the passenger-carrying vehicle cannot do it, a truck must be used where the volume is sufficient.

THE REAL MEANING OF COORDINATION

Dr. G. Lloyd Wilson, of the Wharton School of Finance and Commerce, University of Pennsylvania, in presenting his paper on *The Coordination of Transportation Services*, pointed out that the history of transportation in the United States has been replete with instances of the struggle of rival competing and connecting services, seeking to find their proper places in the transportation system; hence, the present conditions are not unexampled. Mentioning the various instrumentalities of transportation, he stated that the ultimate purpose of each of them is the transportation of goods at the lowest price for the character of service required and that all units of the transportation system must be coordinated and correlated by through-routes, rates and service arrangements if the transportation facilities are to give the most effective service possible to commerce and industry. Topics discussed in his paper include the real meaning of coordination, the place of the railroads in the transportation system, terminal efficiency and some outstanding causes of terminal inefficiency, the coordination of motor-truck with the steam and electric railways and with the steamship lines, the economies possible through coordination, the immediate



H. C. Crowell
Pennsylvania



M. F. Steinberger
Baltimore & Ohio

A PAIR OF RAILROAD REPRESENTATIVES

need of coordinated service, and the role of the motor-vehicle as a coordinator.

Coordination is defined by Dr. Wilson as the regulation and combination of units into a relationship of harmonious action.

The causes of terminal inefficiency discussed by the author include: (a) inadequate freight-station facilities; (b) duplication of freight-terminal facilities; (c) uneconomical railroad terminal services; (d) physical characteristics of terminals, notably in New Orleans, New York City, Chicago, and St. Louis; (e) lack of planning in the layout of cities; (f) narrow streets that cannot carry the present volume of vehicular traffic; and (g) inadequate traffic control.

Regarding the role of the motor-vehicle as a coordinator, the speaker stated that the relative efficiency of various types of carrier for hauls of various lengths in any given district depends upon a number of variable factors, such as the price of fuel and supplies, labor rates, initial costs of facilities, tax rates, condition of highway surfaces, degree of congestion of highways, and the like. According to Dr. Wilson, the only valid statement that can be made is that in general the steam railroad, the electric railway and the steamship function under ordinary conditions more efficiently in long-haul services, whereas the motor-vehicle is more efficient in the terminal and in the so-called short-haul field.



Albert Lodge



F. I. Hardy



J. A. Moyer

THREE WHO PLAYED PROMINENT PARTS AT THE TRANSPORTATION AND SERVICE MEETING



Charles C. Castle
American Car & Foundry
Motors Co.



M. C. Horine
International Motor Co.

AMONG THOSE PRESENT WERE THESE TWO MOTORCOACH MEN

Dr. Wilson's paper will probably be printed in full in an early issue of *THE JOURNAL*.

DISCUSSION EMPHASIZES NEED OF COORDINATION

Francis W. Davis, consulting engineer, stated that in most cases of fleet operation from 10 to 15 per cent of the total operating expenses can be saved by getting down to the fundamentals of the subject and analyzing it thoroughly. A reasonable standardization of equipment would be one of the results of such a study.

J. K. McNeillie, of the Delaware & Hudson Railroad Co., in stressing the need for coordination, discussed three factors necessary for the attainment of this end, the suitable location of highways, the proper organization of motor-vehicle operators to handle the business that should be handled by them and adequate legislation to control all forms of transportation.

B. F. Fitch, of the Motor Terminals Co. said that those endeavoring to ascertain where and how and under what conditions the motor-truck and other motor-vehicle business could fit into the national transportation program find themselves confronted by existing terminal plants that do not conform to this new type of transportation. He believes that the new type of transportation makes possible a complete readjustment in regard to the terminal plant through the simple procedure of turning it inside out, situating the railroad terminals on the outskirts, at the fellow of the wheel, running from that plant into the hub, instead of having the stations at the hub.

Regarding coordination, Mr. Fitch said that his conception of the coordination of the motor-truck with the railroads is the proper allotment of each form of existing transportation facility to the zone in which it can function best.

FLEET MAINTENANCE CONSIDERED

Some Suggestions Offered to Builders—Time-Saving Tools Described

That a distinct opportunity exists for engineers to make improvements throughout the range of motor-truck sizes in the matter of weight for a given load capacity was pointed out by J. F. Winchester, superintendent of motor-vehicle equipment for the Standard Oil Co. of New Jersey, in one of the two papers presented at the Maintenance Session of the Transportation and Service Meeting on the morning of Nov. 17. In the other paper, prepared by A. H. Leipert, of the International Motor Co., but delivered by F. B. Whittemore, of the same organization, a number of special maintenance tools and fixtures were described and shown in lantern slides. Delivery of the papers and extended dis-

cussion on them occupied all of the time of the well-attended session, over which W. M. Clark, of the S. S. Pierce Co., of Boston, presided as chairman.

SATISFACTORY SERVICE REQUIRES SPECIAL FACILITIES

Mr. Leipert's paper, which was delivered first, outlined the requirements to be met to assure satisfactory service to the vehicle owner, asserted that this satisfaction depends largely upon direct control by the builder over the service station and declared that superior service can be rendered only by organizations that have the best facilities for making prompt, accurate and dependable repairs. The author then described half a dozen special tools and fixtures developed by the Mack motor-truck organization for handling repair work on Mack motor-trucks and motorcoaches. These include a dolly for removing the transmission assembly from the chassis, a two-part stand for supporting the transmission unit and the countershaft assembly while work proceeds simultaneously on the two units, another stand for holding the complete transmission assembly when the two units are not to be separated, stands for the motor-truck and motor-coach engines in which the engines can be inverted to facilitate work on the under side, a main-bearing boring-fixture, a connecting-rod straightening and aligning fixture, a connecting-rod-bearing boring-fixture, and a valve-cap removing spanner. This paper is printed in full, with illustrations, in subsequent pages of this issue of *THE JOURNAL*.

CAREFUL SELECTION OF VEHICLES IMPORTANT

Only by proper selection of motor-vehicles for the work they are to do can they be used as a medium of economical transportation, declared Mr. Winchester in his paper. The relation of the vehicle to the work to be done must be considered, as well as the road and climatic and load conditions. Wheelbase; gear-ratios; tire sizes; engine power; body design; rear-wheel, four-wheel or caterpillar drive; and whether the power unit should be a tractor are factors to be considered. Competent disinterested engineering talent should be called in to analyze the problem. Advances in design and equipment have a material bearing in reducing operating costs.

Chassis weights show wide variations, from 1500 to 2980 lb. for a 1-ton chassis with open cab and from 4615 to 5850 lb. for a 2½-ton chassis, said Mr. Winchester. Many are too light, but weight has an important relation to tire equipment. The question of tires must be settled definitely; the vehicle builders have reversed their position with respect to pressures in pneumatic tires and from recommending single rear tires to advocating dual rear-tire equipment.

The four-wheel drive has been improved of late and should not be judged by experience with war-time models. A definite field exists for this type, said the author, who showed half a dozen lantern slides of such a truck negotiating ground



W. M. Clarke



F. B. Whittemore

THE CHAIRMAN OF THE MAINTENANCE SESSION (LEFT) AND ONE OF THE SPEAKERS (RIGHT)

where the two-wheel-drive truck would be ineffective. Six-wheel support seems a logical way to reduce road shock and permit the carrying of larger loads.

One should visualize the results that can be obtained from equipment that is capable of double the mileage of vehicles of 5 or 6 years ago before it reaches the period of complete overhaul, he said. Past failure of the builder to supply adequate service at reasonable prices caused many fleet owners to service their vehicles in their own shops, but the small operator cannot afford to install the necessary equipment for the maintenance of a small fleet. Service organizations have a long way to go before they will attract business that should be theirs.

The importance to the operator of a proper accounting system that includes all items and provides a record of individual units of the vehicle was stressed, as it is important to be able to determine whether it is more economical to overhaul, salvage or trade-in a vehicle. Mr. Winchester showed a number of lantern slides of forms of accounting for overhaul and painting jobs and of stock-charge requisitions used in the Standard Oil Co.'s maintenance plants. The mechanic checks on the requisition forms all replacement parts needed for the job in hand. This method saves time and enables the stock record to be kept more accurately. Another form is a repair order and estimate sheet with spaces for entering the date of the last overhaul and the mileage covered since then.

FLAT-RATE CHARGES BUT HOUR-RATE PAY

In the discussion Frank E. Johnson asked Mr. Whittemore if the Mack dealers pay their mechanics on the piece-work basis when charges for service are made on the flat-rate system. He also asked the approximate cost of the connecting-rod boring-fixture. The answer was that the men are not on the piece-work basis, as this is unsatisfactory because the manager and foreman should be unhampered in moving the men to whatever class of work is deemed best and in putting them on emergency work as occasion requires without causing the men to feel that money is being taken out of their pockets. The policy is to assure good work first and the establishment of cost second. On the same subject, in reply to H. R. Cobleigh, Chairman Clark said that while the piece-work basis would appeal to the fleet operator as a possible way of reducing maintenance cost and perhaps resulting in better work, his experience with flat-rate work on passenger-cars has been that it is not so satisfactory as time work. Frederick L. Johnson, of the Mack branch in Boston, explained that jobs billed out each month on a flat-rate basis are all figured on a time and material basis, the costs are ascertained from this and the variation is adjusted. John W. Brewer, of the International Motor Co., said that he could not remember the cost of the boring-fixture but it would be prohibitive to the owner of two or three trucks.

A. G. Metz, of the Chilton-Class Journal Co., inquired whether the main bearings are always bored with the cylinder-blocks hanging from the crankcase and if this would not result in deflection that would upset the micrometer measurements. To this Mr. Whittemore replied that to have the cylinder-blocks on was important, because deformation comes more from tightening the stud-nuts than from other causes and the blocks reinforce the crankcase.

EDUCATION IN MAINTENANCE MANAGEMENT NEEDED

Need of education in management of the maintenance business was pointed out by R. E. Plimpton, of *Bus Transportation*, in the discussion on Mr. Winchester's paper. No scientific course in such management is offered now and a big opportunity exists, he said, as openings for trained men are occurring constantly. The Society meetings provide opportunities to learn, and early next year the Metropolitan Section is to hold a meeting to which men in local engineering schools are to be invited to hear about the industry and openings in vehicle operation and maintenance work and in research and production work. A. H. Frost emphasized the importance of making written educational matter and instructions brief and snappy and of frequent repetition of oral information, since the average person does not retain

more than 20 per cent of what he is told. Manufacturers of automotive equipment should start schools for the training of drivers and repair men and encourage standardization, said C. E. Hall, who believes fleet owners will be willing to pay for such education of their men.

TERRITORIAL INSPECTORS MAKE CURRENT REPAIRS

To a question put by J. H. Walsh, Mr. Winchester said that his company does not overhaul its vehicles at the end of a given mileage, such as 50,000, but depends upon the reports of inspectors, who are constantly inspecting the vehicles and following-up the work of the general repairmen. Some vehicles remain in condition much longer than others of the same make. Factors that enter into the matter are the drivers, topography of the territory and nature of the roads. Each inspector has 33 or 35 vehicles assigned to him in a given territory and is provided with a car and special tools and equipment for taking care of the trucks. He also instructs the drivers in the care of the machines.

So far as possible, he replied to Mr. Ammerman, an endeavor is made to operate on the unit-repair system and records are kept of the units so that the cost of repair work on each engine, transmission and rear end is known.

To a question as to the economical advantage of installing magazine oilers on truck chassis, Cornelius T. Myers said that with the oilers the amount of greasing labor is reduced to one-third or one-quarter for a given mileage and that wear on the parts is only about one-fifth. The cost of fitting the oilers properly to trucks in service is between \$70 and \$80; if they were put on at the factory as regular equipment the cost would be less than \$30. Greasing in the usual way costs \$27 or \$28 per truck per year in one of the largest fleets in the world and bearing parts must be replaced on the average after 23 months. Since installation of the oilers it has not been found necessary to replace any bearing in 28 or 29 months and hardly any wear can be found.

As an operator, Mr. Winchester said he prefers that when a manufacturer has brought out a properly engineered model he incorporate improvements from time to time rather than make a radical change of model after a period of years, but the operator should be notified at once of all changes.

MACHINES AND MELODY MINGLED ON TRIP

Large Group Instructed in Maintenance and Testing, Entertained by Charleston

When 203 Society members and guests climbed into motor-coaches for the inspection trip on Wednesday after lunch, a new high-water mark for attendance at such functions was reached.

The first stop was the East Cambridge plant of the

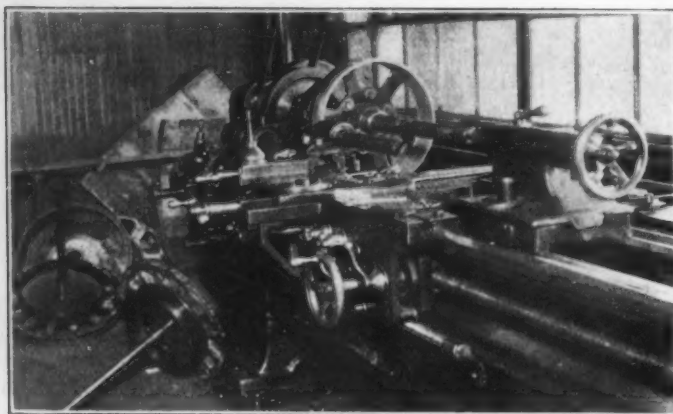


F. R. Filter
Standard Oil Co.



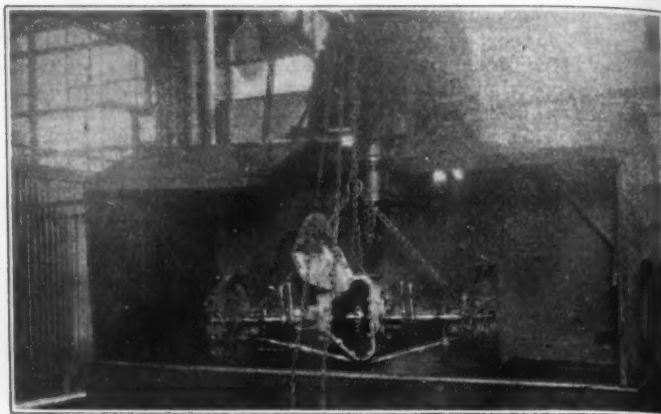
D. A. Fales
Massachusetts Institute of
Technology

THE HOSTS OF THE MEMBERS WHO MADE THE INSPECTION TRIP



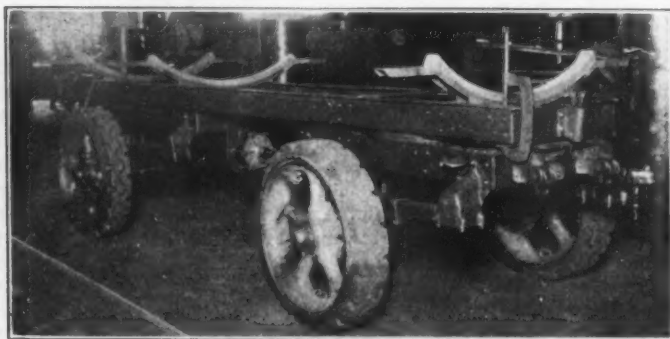
STEEL BRAKE-DRUMS USED

As Malleable-Iron Brake-Drums Do Not Stand Up in Service, They Are Replaced by Steel Drums Designed by the Company When the Trucks Are in for Overhaul. The First Steel Brake-Drum Placed in Service Has Yet To Show Signs of Wear



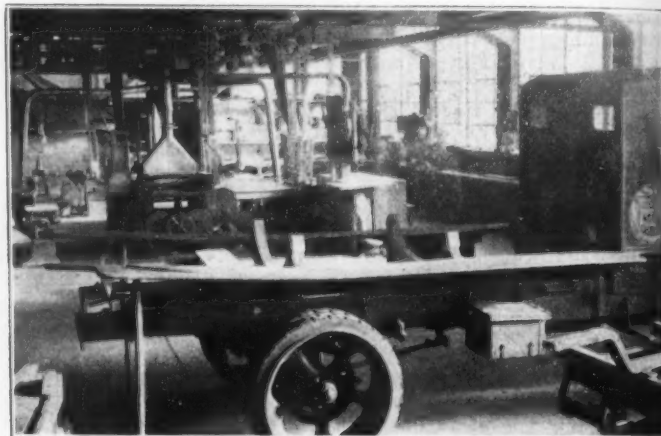
CLEANING TANK FOR PARTS AND UNITS

The Work of Cleaning the Parts and Units by Hand Formerly Required from 15 to 18 Men. As a Result of This Process the Plant Is Cleaner than the Average Manufacturing Plant



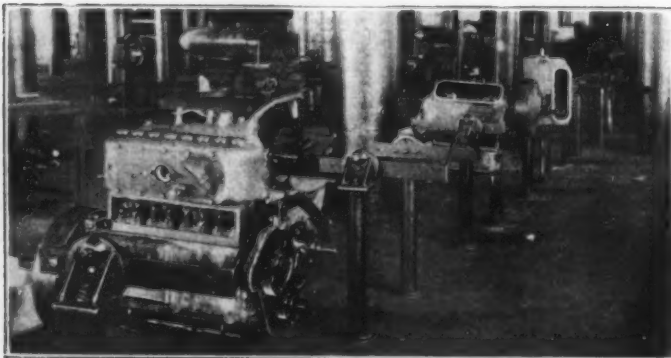
TRAILER DESIGNED BY F. R. FILTER

To Overcome Troubles Experienced in Trailer Application, a Special Trailer Has Been Designed



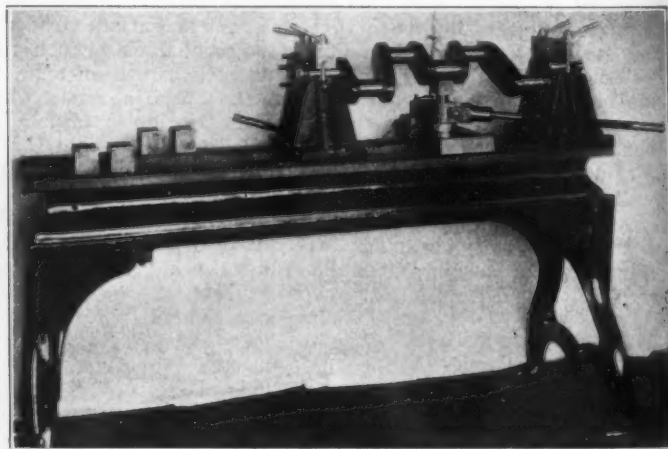
WOODWORKING DEPARTMENT FOR BODIES

All Cabs and Bodies Used by the Company Are Manufactured in This Department



ENGINE ASSEMBLY STANDS

Special Stands Designed by the Company Are Used To Hold the Engines While the Overhaul Work Is Being Done



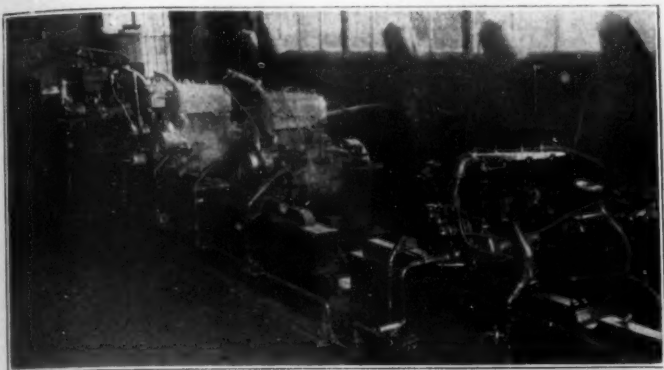
CRANKSHAFT STRAIGHTENING MACHINE

This Machine, Built by the Company, Is Used in Case Inspection Shows That the Crankshaft Has Been Distorted

Standard Oil Co., a modern, fully equipped five-story service station with a total floor space of 114,000 sq. ft. Here a force of 260 performs the maintenance work on a fleet of 1600 vehicles that operate in all parts of New England, the average number being overhauled at any one time being 115.

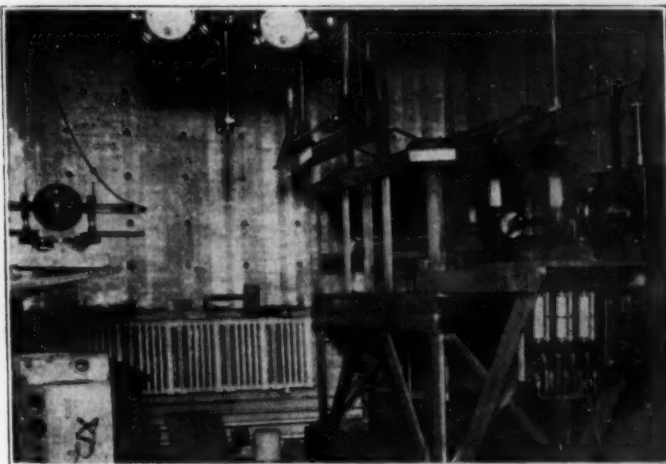


AT THE LEFT, ONE CORNER OF THE MAIN STOCK-ROOM
Over \$90,000 Worth of Parts Are Carried in Stock in Specially Constructed Drawers Worn Parts Are Held until a Run of 100 Parts May Be Routed through the Machine-Shop



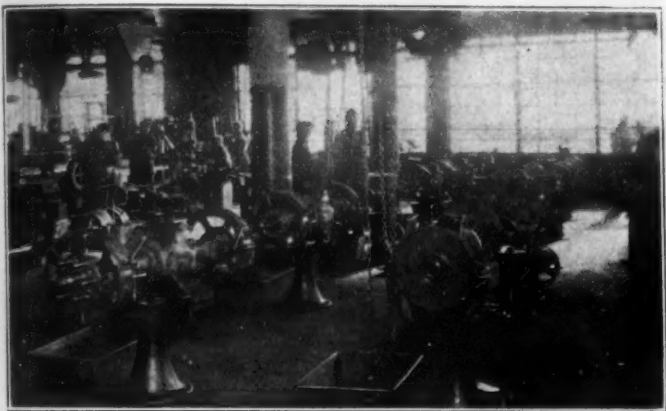
STANDS FOR RUNNING-IN ENGINES

After Each Engine Is Assembled, It Is Run-In for Several Hours Before Being Put on the Dynamometer Stand for Power-Characteristic Tests



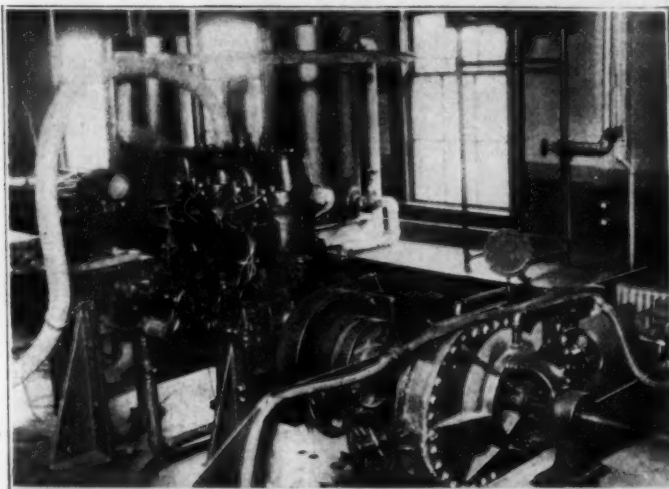
X-RAY LABORATORY

A Corner of the X-Ray Laboratory Where the Studies of Automotive Metal Parts Are Made. An Interesting Application Is the Control of Foundry Practice



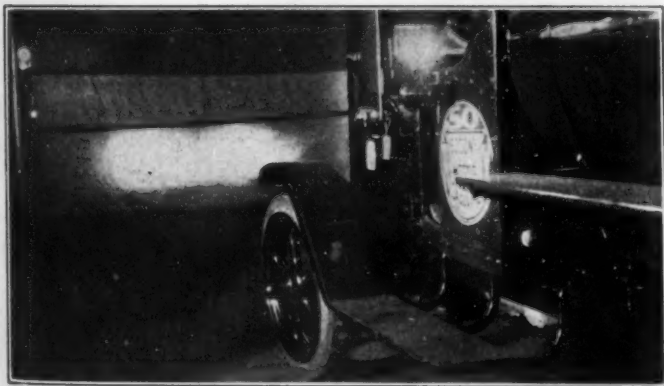
OVERHAUL ROOM FOR AXLES AND TRANSMISSIONS

Special Stands Designed and Built by the Company Hold the Material, and All Units Are Handled by Hand Hoists



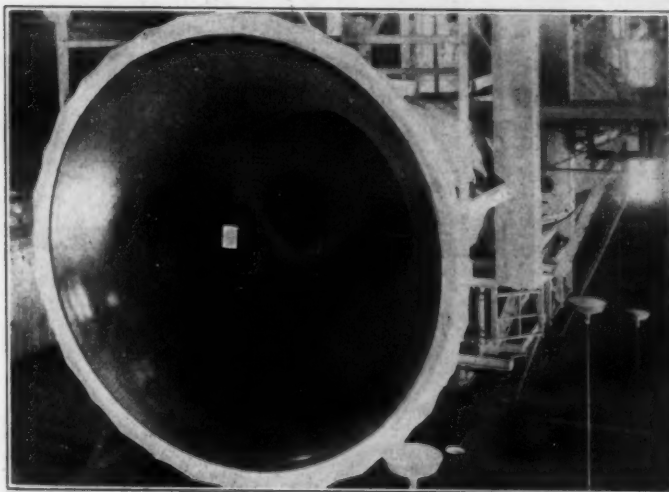
WATER BRAKE FOR TESTING ENGINES

The Water Brake Is Used for Testing Small Commercial Engines



STAND FOR TESTING AUTOMOBILE HEAD-LAMPS

Before the Trucks Are Put Back in Service Headlights Are Focused in Accordance with the State Requirements. The Brakes Are Also Tested at This Point



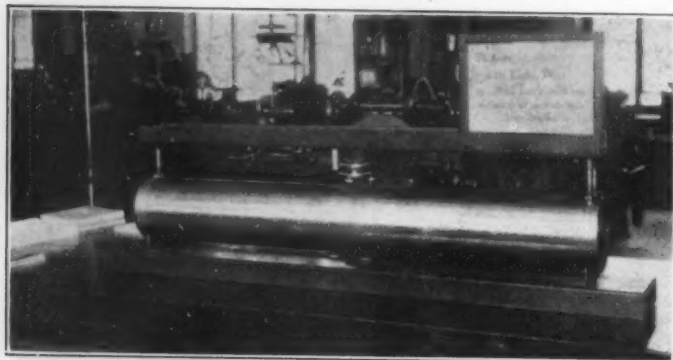
ONE OF THE WIND TUNNELS

The Aeronautical Laboratory Is Equipped with Two Wind Tunnels for Model Testing in Aeronautical Research Work. The Larger Tunnel Is Shown in the Photograph and Its Electrically Driven Unit Is Capable of Producing Air Speeds Up To 90 M.P.H. All Recording Scales Are Electrically Balanced



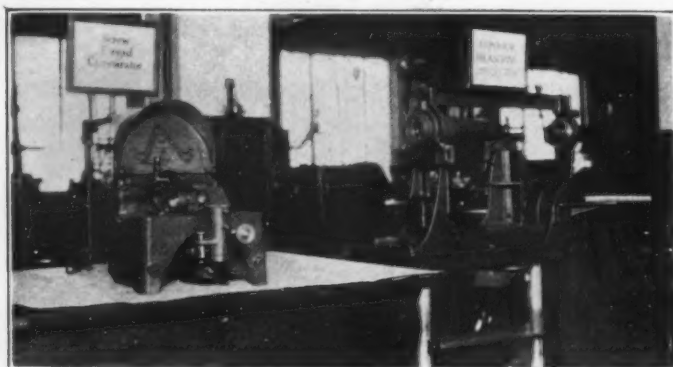
AT THE LEFT, ENGINE TESTING LABORATORY

The Equipment in This Part of the Building Is Largely Standard Government Engines Used for Tanks, Tractors and Airplanes and the Laboratory Is Equipped So That Complete Engine Tests Can Be Made



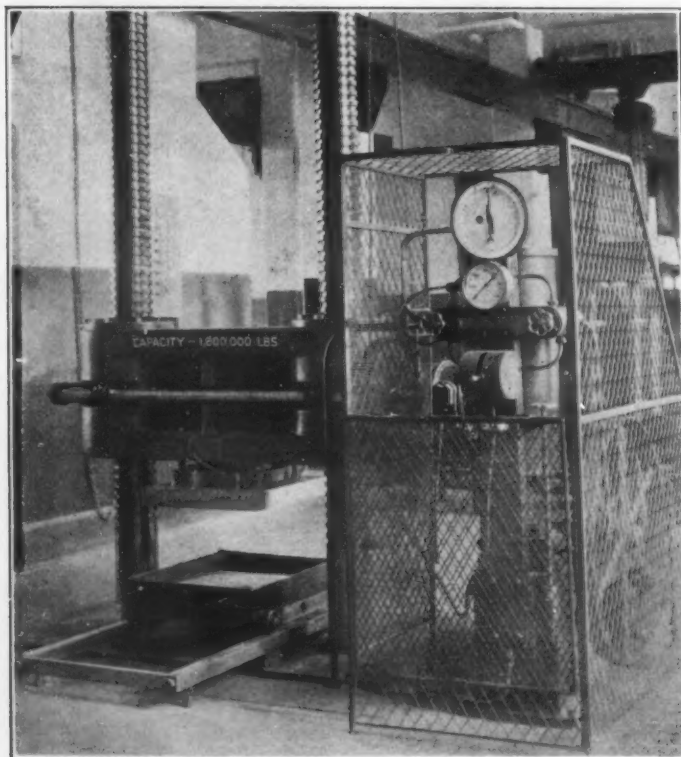
MEASURING DEFLECTION BY LIGHT WAVES

This Machine, Using the Principle of Interference of Light Waves, Will Measure the Deflection of a 5-In. Steel Shaft to 0.0000001 In.



SCREW-THREAD COMPARATOR

A Gaging Device in Which Actual Screw-Threads Are Greatly Magnified and Compared with Standard Requirements by Light Reflection. The Contour Measuring Projector Is Shown at the Right

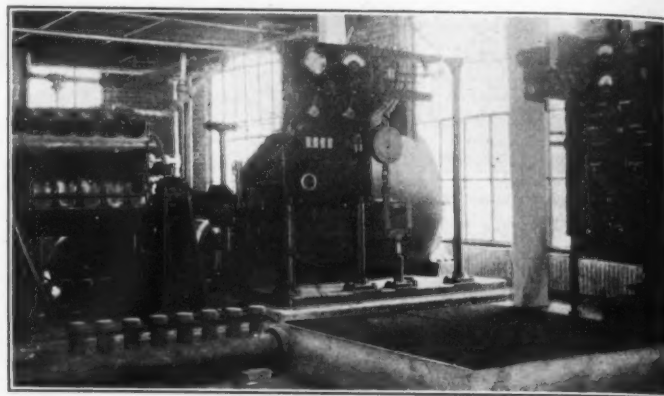


COMPRESSION TESTING MACHINE

One of the Many Pieces of Equipment in the Laboratory for Testing All Types of Material. The Machine Shown Has a Capacity for Testing Materials under Compressions Up To 1,000,000 Lb.

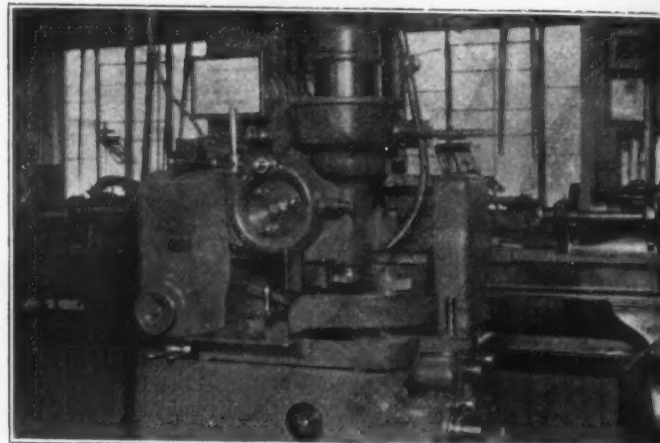
Some of the accessories used, such as cans, funnels and greasing-pots, are manufactured also, and cabs and woodwork for bodies are made in a special woodworking department. Especially impressive are the carefully planned system for handling all material throughout the plant and the persistent and successful efforts to eliminate grease and dirt in all operations.

After the more serious business of inspection was finished, a light lunch was served and the visitors were treated to



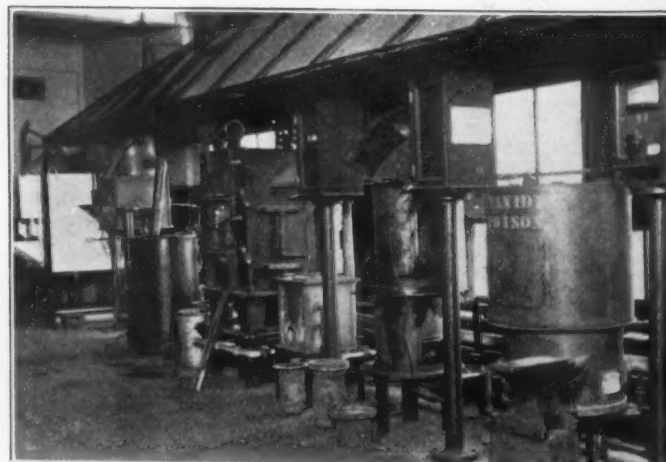
AERONAUTIC ENGINE DYNAMOMETER TEST

The 600 Hp. Dynamometer and a Liberty Engine Are Shown Ready for Actual Test. This Part of the Laboratory Is Equipped Also with Hot-Air Gas, Semi-Diesel, and Diesel Engines



HIGH-SPEED GEAR-SHAPING MACHINES

The Equipment of the Machine-Tool Laboratory Includes High-Speed Automatic Gear-Shaping Machines for Producing Spur and Helical Gears



HEAT-TREATING LABORATORY

One Corner of the Heat-Treating Laboratory Showing the Furnaces Used in Some of the Special Heat-Treating Tests

an entertainment, the informality of which was a delightful feature. Employees were called from various positions throughout the plant to contribute by their talents to the enjoyment of their guests, some to perform in the orchestra, one to sing and another to give a very creditable exhibition of the Charleston.

Time permitted of only a hurried inspection of the laboratories and automotive testing equipment at the second place scheduled, the Massachusetts Institute of Technology. The most complete set-ups for the testing of tank, tractor, automobile, and aeronautic engines as well as gas and Diesel powerplants were viewed, and dynamometers of various types were pointed out to the visitors. An item of especial interest was the wind tunnel for aeronautical research with its electric balancing devices and electric control of air-speeds to facilitate accuracy.

The machine-tool laboratory, where courses in operating machines are given, covers every angle of small-tool equipment and its production. The visitors were shown how heat-treating of metals, the strength of materials and other phases of automotive material investigation are studied in the various laboratories devoted to such work. The use of the X-ray for material inspection and the part played by it in controlling foundry practice proved to be of unusual interest, as well as the photoelastic studies of the strength of gear-teeth being carried out at the Institute.

THE BANQUET A FESTIVE OCCASION

State and City Officials Welcome Guests and Cunningham Gives Principal Address

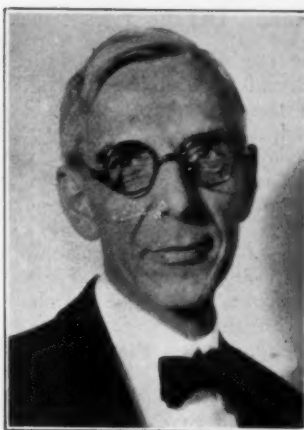
More than 300 members and guests of the Society assembled in the tea room of the Copley-Plaza Hotel, Boston, on the evening of Wednesday, Nov. 17, to take part in the Transportation and Service Banquet. At the conclusion of the dinner, when cigars and cigarettes were lighted and the spirit of good-fellowship and contentment prevailed throughout the gathering, H. E. Morton, a prominent member of the New England Section, arose from his place at the center of the speakers' table and introduced with appropriate remarks all who were seated at the speakers' table, with the exception of those who were later introduced by the toastmaster. Speaking of the interest of New England, and in fact the whole Country, in automotive engineering as it applies to transportation and service, Mr. Morton touched briefly upon the work of the New York, New Haven & Hartford Railroad Co. and its subsidiary, the New England Transportation Co., in the operation of motorcoach lines during the last year and a half, and then introduced as the toastmaster the gentleman who is vice-president of the former organization and president of the latter, namely, Robert H. Newcomb.

NEWCOMB URGES COOPERATION

Toastmaster Newcomb spoke with genial earnestness of the wisdom of the transportation industry in having the representatives of the older type of transportation get together with the newer type, realizing that both types are treading the same path and can further their mutual interests much better through friendship than through enmity.

WALSH DELIGHTS HEARERS

Senator-elect David I. Walsh, formerly Governor of Massachusetts, after an introduction in which the toastmaster characterized him as the man whom every citizen in Massachusetts is proud to own as one of his leaders, expressed his pleasure at having the opportunity to speak before automotive engineers regarding some of their problems in which, he said, public servants should be interested. After referring in complimentary fashion to the work of the Society in directing the development of a means of transportation of almost unlimited possibilities, Senator-elect Walsh assured his audience that, in returning to the Senate, he would, as in his former term, direct his efforts to the advancing of legislation calculated to (a) extend our system of Federal highways, (b) bring an end to that form of



R. H. Newcomb



Photograph by Bachrach
W. J. Cunningham

THE TOASTMASTER (LEFT) AND THE PRINCIPAL SPEAKER (RIGHT) AT THE TRANSPORTATION AND SERVICE BANQUET

nuisance tax which hampers the industry and (c) provide for reasonable regulation of motor transportation. Outstanding in Mr. Walsh's comments on these three points was his reference to the Federal tax upon automobiles as a war tax, imposed to meet the exigencies of a national emergency; he sees no reason why this tax should be continued and promises that, in whatever legislation may be offered in the next Congress to secure tax reductions, he will take up the fight to lift from the automobile builder and purchasers this hampering burden.

BOSTON'S TRAFFIC PROBLEM

Hon. Charles G. Keene, president of the Boston City Council, spoke words of welcome on behalf of the City of Boston. He represented Mayor Malcolm E. Nichols who was unable to be present. Mr. Keene in welcoming the automotive engineers hoped that they had heard of Boston's traffic problem and had come to help in solving it; he then pointed out some of the features of the problem. Regarding the attitude of the City toward a street-car line and a motorcoach line, he pointed out that the former maintains the track and 18 in. from either rail, whereas the motorcoach line, although hard on the pavings, assumes no such burden.

Calling attention to the fact that Boston's traffic problem is complicated by the presence in the city of people from the suburbs and other places outside Boston, he expressed his view that the most vital factor in the problem is caused by the parking of cars on crowded streets. He felt that, even with a third of some streets used for car-tracks and with the difficulties caused by the fact that many of the streets are crooked or narrow, the streets of Boston could take care of the traffic if the full width of the streets could be used for purposes of traffic and not, as now, partially for garage purposes. As Mr. Keene said: "You can not use streets for traffic and for a garage at the same time."

As a means of relief, the speaker suggested either that the space under the Public Gardens be made available for parking purposes, or that private vehicles be allowed to come no nearer the congested area than certain specified places. He spoke also of the possibility of constructing enormous garages in the congested area, but felt that business men and property-owners would hesitate to adopt this measure.

Automotive transportation men and men engaged in rail transportation should recognize, said Toastmaster Newcomb, that each type of transportation interest has as its aim the service of the public in distribution. He felt that this view of the economics of transportation would be demonstrated and justified by the principal speaker of the evening whom he then introduced in his inimitably gracious manner: Prof. William J. Cunningham, James J. Hill Professor of Transportation in the Graduate School of Business Administration of Harvard University.

A PROBLEM OF GENERAL INTEREST

Professor Cunningham, at the beginning of his address entitled *Motor-Vehicle and Railroad Transportation: Economics of Coordination*, spoke of the fact that this problem of coordination is one of outstanding interest to every citizen; it concerns, he pointed out, not only those in the automotive industry and those connected with railroads, but in many ways, both directly and indirectly, it affects the general public. The problem is more than one in engineering and business administration; it is one of economics and public policy. The theme of Professor Cunningham's discourse was the development of motor-vehicles as an agency of transportation, the characteristics of the situation as it exists today, the effect of motor-vehicle development upon railroads, and the desirable policies of coordination.

After a reference to the comparative youth of the automotive industry, Professor Cunningham spoke of its spectacular development, saying that, even with due allowance for the wonderful expansion of railroad mileage and service, the growth of motor-vehicles has in degree far outstripped railroads in their most active quarter-century of development.

Several interesting comparisons were made between highway and rail transportation. The combined investments in motor-vehicles and hard-surfaced highways were shown to have reached a total of \$26,000,000,000, which is \$3,000,000,000 in excess of the total investment in railroads, including \$6,000,000,000 in railroad equipment and \$17,000,000,000 in right-of-way, track and structures, stations, terminals, shops, and other facilities. The number of garagemen, repair-shop employees, professional chauffeurs, and professional truck drivers is 1,870,000, or about 100,000 more than railroad employees of all classes.

Regarding the relative amounts of business done by the two types of transportation, the speaker showed that it is in the passenger service that the motor-vehicle in 25 years' development has forged ahead of the century-old railroads. In freight service, he pointed out, the motor-truck is not yet within hailing distance of equality with railroads in ton-miles, although it has potentialities that are difficult to measure.

RAILROADS NOT TO BE SCRAPPED

Professor Cunningham warned against the tendency to predict that in the not-distant future the railroads are doomed to take but a minor place in transportation as highways are further extended and improved and as the motor-vehicle increases in number and effectiveness, as such a prediction runs counter to economic facts. The question is not, he said, the survival of one and the downfall of the other; it is a question of finding the desirable economic balance, a fairly definite limitation of field, with wise coordination, so that in the two

fields each agency of transportation can function with maximum economic efficiency.

The superiority of the motor-truck, the speaker stated, is evidenced in the short-haul, less-than-carload traffic, especially in the movement of high-grade manufactured products and certain kinds of raw materials in limited quantities; the railroads are supreme in long-haul traffic. Professor Cunningham brought up the difficult question of determining the critical point in length of haul, that is, the distance within which the motor-truck is economically preferable and beyond which the railroad is the better agency; he did not, however, think it practicable to set a definite limit at this time, as the distance will vary with local conditions, including the character of the highways, the capacity of existing railroads, the volume of traffic, and the nature of the commodities. Recent surveys of highway traffic, he said, indicate that about 80 per cent of the motor-trucks are operating within a zone of less than 30 miles.

WHAT SHOULD BE DONE?

A sound policy of transportation coordination, according to Professor Cunningham, would seem to dictate that the railroads, instead of looking upon the motor-truck as a harmful competitor, should recognize it as (a) a desirable means of relief from the responsibility of providing freight-house and other terminal facilities for that traffic which is most burdensome from the viewpoint of operation and car utilization and least desirable from the viewpoint of net revenue, (b) a substitute for the expensive and facility-consuming way freight-trains, (c) a potential creator of new traffic by bringing to the railroad freight from remote territories, and (d) the instrumentality that will make possible the service of store-door delivery and the use of unit containers.

In passenger service, on the other hand, the motor-vehicle is seen to have made serious inroads on railroad passenger revenue. The decrease is found among the short-distance, local passengers, not in the long-distance riders, and not in the commutation or suburban passengers. Faced with this situation, Professor Cunningham said, the railroads can either continue their unprofitable local passenger-trains, cutting down the number of trains to the lowest limit permitted, economizing in every practicable way and attempting to make up the loss elsewhere, or they can go into the motor-coach business themselves. The speaker discussed the feasibility of this latter alternative, making reference to the operations of the New York, New Haven & Hartford, and the Boston & Maine Railroads in this field.

THE SPEAKERS' TABLE

Besides Master-of-Ceremonies Morton, Toastmaster Newcomb, Senator-elect Walsh, Hon. C. G. Keene and Professor Cunningham, the following were seated at the speakers' table: F. W. Ball, W. M. Clark, B. V. Crandall, A. W. Devine, Dean A. Fales, F. I. Hardy, A. W. Herrington, F. C. Horner, W. P. Kellett, C. S. Lake, C. F. Park, A. J. Scaife, F. J. Scarr, S. W. Stratton, G. S. Whitham, and J. F. Winchester.

SELLING TRUCK TRANSPORTATION

Importance of Organization, Personnel and Equipment to Profitable Service

If the Society, through meetings of this kind, does not accomplish anything else than to break down opposition and put the steam and electric railway men into the transportation business, regardless of whether it is by railway or motor-truck, motorcoach or taxicab, or whatever it is, then the Society will have accomplished wonderful results

observed A. J. Scaife, of the White Motor Co., in the course of some pertinent remarks that he made as chairman in opening the Motorcoach and Truck Operation Session of the Transportation and Service Meeting on the morning of Nov. 18. Some men feel that the motor-truck or the motorcoach has no business in the transportation scheme, he said, but



S. W. Stratton



C. F. Park

TWO OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY FACULTY WHO SAT AT THE SPEAKERS' TABLE

fortunately this is shared by very few. The bigger men are coming to realize that the steam-train, the electric car, the internal-combustion engine, whether on rails or rubber, are simply tools in the transportation scheme, and they will take advantage of these tools and fit them in to best advantage. Eventually the economical unit of transportation will be the one that will be used in the service in which it belongs. We are all in the transportation business; the barriers will be wiped away and we shall all be operating along the same line of giving the most economical transportation service, whether it be on water, on land, or in the air and whether it be individual or mass transportation.

THE REAL MERCHANDISERS OF TRANSPORTATION

Motor-truck operators, particularly those whose trucking service is their only means of revenue, are the real merchandisers of transportation by highway, was the opinion expressed by C. S. Lyon, of the Motor Haulage Shop & Garage Corporation, of Brooklyn, N. Y., in his address on Merchandising Motor-Truck Transportation. He pointed out, however, that many failed to realize the importance of conducting this service on a businesslike basis and said he believes concentration must be directed toward men and equipment if their service is to be merchandised profitably. Stability of the business is in direct proportion to the strength of the supporting organization and its preparedness for weathering a period of depression; that is, a personnel equipped with the knowledge to function in case of emergency. Motor-truck transportation companies require reserve equipment and service facilities the same as the railroads or a manufacturing organization, as much if not more skill in the selling of their service at a profit, as good an accounting system and as efficient supervision and dispatching. Before this form of transportation can be regarded as a permanent link in the general transportation system, it must be conducted on a businesslike basis, which can be determined only by survival of the fittest.

PROFITABLE GARAGE AND HAULING EQUIPMENT

Following his summation of some of the broad principles of the problem, Mr. Lyon showed a series of slides of the Brooklyn plant of his company, outside and inside, for the storage and maintenance of a fleet of 168 motor-trucks and vans. Types of vehicles were also shown. Of particular interest were the electric dynamometer by which much greater efficiency of the vehicles has been secured; the compressed-air and water gun for washing the trucks quickly; a new light duralumin van-type body for 20-ft. trailers; and triple tire equipment on the tractors.

The dynamometer has eliminated more lost truck-time than any other piece of apparatus he has seen, said Mr. Lyon, as engines can be tested for power without withdrawing the truck from service by installing a spare engine in the chassis. When an engine is taken off the dynamometer and put in the chassis it is ready to function with a reasonable degree of efficiency for between 25,000 and 30,000 miles. With the "blunderbuss" washing equipment, a chassis can be cleaned ready for painting in about 3½ hr.

The reason for adopting triple tires was that in light runs over the bridges across the East River into Manhattan traction was difficult to obtain with the tractors in wet weather. These tires have a 14-in. face and since their adoption they have given as much as 35,000 miles compared with 12,000 miles for dual tires on some of the other tractors.

An installation of 29 trailers with 20-ft. bodies for freight interchange between Pier 22, New York City, and the terminals in Brooklyn and Long Island City has resulted in the elimination of peddler trains on the Long Island Railroad as far east as Port Washington, N. Y., said Mr. Lyon. The new duralumin bodies made for these trailers weigh only 2750 lb. as compared with 5400 lb. for the conventional wood-and-steel body. They are not painted and after 6 months of 24-hr. service they look as good as when new.

Mr. Lyon's address was received with enthusiasm and elicited much interested discussion and numerous inquiries regarding different points touched upon, members and guests



C. S. Lake



C. S. Lyon

AT THE LEFT A PROMINENT FIGURE AT THE MEETING AND AT THE RIGHT THE AUTHOR OF A PAPER AT THE MOTORCOACH AND TRUCK OPERATION SESSION

present seizing upon the opportunity to get authoritative information from a man actively and largely engaged in truck operation. Among those who participated were N. D. Ballantine, of the Seaboard Air Line; R. E. Plimpton, of *Bus Transportation*; Chairman Scaife, of the White Motor Co.; J. F. Winchester, of the Standard Oil Co.; F. C. Horner, of the General Motors Corporation; C. M. Manly, of New York City; A. W. Einstein, of the National Retail Drygoods Association; Irving Malkin, of the Malkin Motor Freight Co.; Cornelius T. Myers, of the Chassis Lubricating Co., Inc.; Edward F. Loomis, of the National Automobile Chamber of Commerce; C. D. Smith, of the Beaver Valley Motor Coach Co.; and C. S. Lake, of the Chesapeake & Ohio Railroad Co.

FLEET STANDARDIZATION AND MAINTENANCE

G. T. Seely, of the Chicago Motor Coach Co., author of the only other paper for the session, was detained in Illinois to attend an important meeting of the Illinois State Commission on matters in which his company is vitally interested; therefore Chairman Scaife asked F. C. Horner to read the paper, entitled *Standardization of Equipment and 100-Per Cent Maintenance for Successful Motorcoach Operation*. This paper is printed in full in this issue of *THE JOURNAL*. Discussion on it was omitted at the meeting, as Mr. Horner did not deem it proper to answer questions on another man's paper and suggested that questions be addressed to the New York City office of the Society to be forwarded to Mr. Seely, the questions and answers to be published in *THE JOURNAL*.

ANSWERS TO OPERATORS' TIRE PROBLEMS

Laboratory and Service Studies of Solid, Cushion and Pneumatic Tires

Under the title, *the Motor-Truck Tire and Its Relations to the Vehicle and to the Road*, James A. Buchanan, of the Bureau of Public Roads, presented, at the Tire Session of the afternoon of Nov. 18, data compiled from reports of research conducted by the Bureau of Public Roads, the Iowa State College and the Johns Hopkins University, thus reviewing such material as has so far been made available to the public on this subject through the research projects of the Bureau alone or in cooperation with the Society of Automotive Engineers and the Rubber Association of America or one of the above-mentioned institutions.

IMPACT TESTS

In reviewing the results of these tests the total vertical reaction between the road surface and the truck wheel obtained with special apparatus was expressed in pounds as a percentage of the static wheel load for each of the test conditions employed with truck sizes varying from 1 to 5



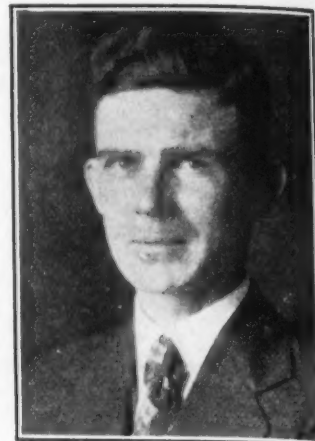
L. W. Fox



J. M. Linforth



A. L. Schoff



James A. Buchanan

FOUR MEMBERS OF THE TIRE SESSION AUTHORS' SEXTET

tons and equipped with various combinations of size and type of tires.

The curves shown indicated that excessive total loads have a tendency to reduce the differences between cushioning qualities of tire equipment so long as the tires are able to carry the loads and that the relative impact effects of trucks of various capacities become more nearly identical as the percentage of overload increases.

The effect of solid tires at speeds up to 5 m.p.h. increases while that of pneumatic tires remains about constant. Between 5 and 15 m.p.h. the impact force for solid tires increases much more rapidly than that for pneumatic until at the latter speed it is approximately three times greater.

For the same motor-truck, load, speed, and respective tire equipments using pneumatic, new cushion and new and worn-out solid tires, a comparison of results showed the impact effects of worn-out solid tires even on smooth highways to be such as to demand the serious consideration of both motor-truck owners and highway officials and justified the conclusion that expense can be materially lowered for both parties by adhering to the use of reasonably good tire equipment with reasonably loaded vehicles.

From the results of a series of laboratory tests the impact of a solid tire worn to about 50 per cent of its original over-all height was shown to be about 250 per cent of the corresponding reaction of that tire when new. It was pointed out that this relation has been substantiated for motor-truck tires in actual service during the course of an extended series of tests concerned with the effect of tire height on motor-truck impact reactions, the data on which have not yet been released by the Joint Committee.

Quoting from Bulletin 67 of the Iowa State College, tabulated values were given for combined air and rolling resistance, and gasoline consumption, for various speeds, tires and road surfaces.

CUSHION TIRES AND THEIR EFFECT ON THE OPERATOR'S TIRE PROBLEM

A. L. Schoff in treating this subject reviewed briefly the early history and comparatively recent rapid growth of the cushion-tire business. Attention was drawn to the importance of providing in cushion-tire design a correct tread shape and a proper profile with suitable internal cavity or its equivalent.

A cushion tire possesses the following specific qualities, all of which to some extent affect the tire problem of the operator:

- (1) Maximum cushioning consistent with long mileage
- (2) Cushioning that is affected to the minimum extent by tire wear or aging
- (3) Suitable tractive and non-skid properties
- (4) Safe lateral control
- (5) Low cost per mile of operation
- (6) Toughness to resist abrasion and cutting

For an operator to expect to receive maximum tire performance with a tire of any type, he should be able to furnish accurate data on all operating conditions and then, and only then, can the most economic installation be worked out.

Unfortunately, for the entire industry, the motor-truck builder is in many cases very largely responsible for the lack of satisfactory tire performance. Too few motor-trucks are produced, even today, which are arranged so that the operator can install on the vehicle the oversize tires that he finds necessary without making expensive alterations to either wheels or bodies or both. This statement holds equally true for motor-trucks produced for pneumatic, solid or cushion tires.

Data were given from various fleet operations to support the claims that a suitable cushion tire will give the greatest number of days of uninterrupted service or highest average ultimate mileage of any tire today available and that mileage records of 50,000 to 60,000 miles per tire are frequent and the operator can reasonably expect upward of 30,000 miles on the average, without any lost time for tire changing.

While the tire cost per mile with good cushion tires will not be very different from that obtained with good solids, yet uninterrupted service, due to less frequent tire renewals, counts heavily in favor of cushion tires. In cushion tires the cushioning properties closely approach those of pneumatic tires.

Mr. Schoff reviewed the reports of several operators showing savings effected by cushion tires as compared to pneumatic tires through elimination of tire changes and delays caused thereby, cost of tire repairs, investment in spare tires, lost or stolen spare tires, cost of tire chains and injury to tires caused by them, and reduction in frequency and cost of vehicle overhaul.

As an illustration of the adaptability of cushion tires to meet unusual conditions and accomplish desired results in specific cases through special designs, a "Mud Hen" tire was shown having a contour approximating a loaded pneumatic tire. This peculiar type of tire was reported to be giving an excellent account of itself in the heavy going in oil fields and on sandy roads for which the pneumatic tire has alone been considered satisfactory.

Many indirect savings are effected by the use of cushion tires. Safety is a matter of ever increasing importance. If accidents are reduced, shop repairs and insurance premiums are reduced accordingly. Cushion tires, due to greater flexibility and more effective tread design, reduce skidding as well as decrease forward sliding when the brakes are forcibly applied and therefore do reduce accidents. A truck in an accident may lose a day or several days at \$30 or \$40 per day, besides the cost of repairs. The loss may easily amount to a few hundred dollars. Insurance premiums in a fleet operating on an experience basis are, of course, reduced as accidents are reduced. A survey on a fleet of 19 trucks in New York City by an outside engineer revealed that, since

cushion tires were used, the accident premiums were lowered \$1,600 per year or practically \$50 per truck.

Due to cushion tires giving better riding qualities than solid and fewer delays than pneumatic tires, a greater daily mileage can often be secured per truck, bringing down yearly operating costs per mile as well as increasing unit products delivered per day.

Eliminating spare tires releases inventory investment and repair crews as well as emergency service calls. It also eliminates loss through the theft of valuable spare tires.

The cushion tire has by its own merit reached its present recognized position of importance in the industry through overcoming the operators' great skepticism as to its real ability to perform and by overcoming a higher initial cost by showing lower unit costs. It can and does now perform excellently on a wide range of trucking problems.

J. M. Linforth's paper on the Importance of Tire Service in Motorcoach and Truck Operations reported the results of studies of pneumatic tires principally on motorcoaches and covered causes of road delays, distribution of flat tire changes and brake-drum beat as affecting tire performance. The paper is printed in full in this issue of THE JOURNAL.

ECONOMIC SOLID-TIRE OPERATION

L. W. Fox for the purposes of his paper assumed solid tires to include that class of tires which are built of solid rubber as contrasted to those containing an air cavity, even though some of these may be classed as heavy-duty cushion-tires.

To make definite recommendations of tire equipment for vehicles of a particular load rating before they go into service has proved impractical. This is brought about through the variation in wheelbases, location and type of body and actual load carried. Operators also differ in their ideas of economical loading, varying from rated load to 100-per cent overload.

Using plain tread tires in all classes of front-wheel service has been found more economical and more satisfactory. There is no reason for using a non-skid tire in front wheel service. Tires that have the tread broken up by design wear faster and are more susceptible to uneven wear caused by mechanical irregularities. Where trucks are operating over improved roads at moderate speed, a type of tire having a continuous tread will give maximum mileage. Tires with a non-skid tread pattern provide more traction at the sacrifice of mileage but have proved to be the best type of tire for long-distance hauling where heat is the chief source of trouble, through the greater radiating surface. If the truck is to be operated over unimproved roads, still more traction is necessary. Tires best adapted to this type of service are those designed so that the soil accumulating in the design is readily displaced upon the succeeding contact with the road, leaving the design free to grip and give traction.

For low cost per mile of tire operation, smooth-tread tires unquestionably rank first. This general type of tire gives the maximum of mileage with a fair amount of cushion and

traction. The non-skid tire would be second choice. Whenever the tread of a tire is cut up into a design, less rubber is in contact with the ground and consequently a higher intensity of pressure per square inch occurs. This must result in faster wear. Also, these types of tire are more susceptible to uneven wear through excessive speed or overload. The traction type of tire with side indentations is designed purely for traction in soft going and is not adapted to exclusive improved road service and ranks third in cost per tire mile.

Excessive speed generates heat within the tire faster than the compound can dissipate it, resulting in disintegration or actual melting of the compound and formation of a gas that blows through the tread or side-wall, ruining the tire, as shown in the accompanying illustration. Excessive speed also causes greater tire action and aggravates uneven wear, as well as fast wear. The load and speed that the solid tire will stand have limits, and if the satisfactory operating conditions for the tire are exceeded, causing blow-outs, the operation is beyond the range of solid tires.

Overload, the effects of which are well known to most operators, cannot be over emphasized. It causes a general breakdown of the tire compound in a manner shown. This action may be started through one heavily overloaded trip and will continue though the tire is not overloaded thereafter. Removing tires, because of this condition, even though only half worn out, is not uncommon.

Mechanical irregularities often result in premature tire failure. Among the most common of these are improper wheel-alignment, loose wheel-bearings, loose bushings, loose steering-gear, front axles out of position, and improper brake adjustment. A bent rim starts separation, which soon causes tire removal.

Improper use of chains, such as being drawn too tight and left on when not needed, results in excessive strain on the tire at one point and cutting of the compound. Car-track riding overloads one side of the tire, breaking down the compound at that point.

EFFECT OF BRAKE-DRUM HEAT ON MOTORCOACH TIRES

C. W. Bedford and Ernest Blaker reported the results of a laboratory study of the effect of brake-drum heat on tire temperature made on a 25-hp. Sprague dynamometer tire-testing machine using four different wheels, 20 and 24-in. standard Budd disc wheels, a 20-in. Motor wheel and a 20-in. Parker wheel. Two cast-steel brake-drums were used. The first had the usual outer corrugated surface extending from the flange part way across the outside of the drum. The other was a similar drum which had the corrugations removed and replaced by a strip of Goodrich super-heat packing 1/32 in. thick, held in place by thin wire.

Room temperatures in the neighborhood of the dynamometer were registered on a recording thermometer. Brake-drum temperatures and temperatures of the inter-face between beads and rims were determined by thermocouples of copper-advance wire and a potentiometer indicator. Two



TWO CAUSES OF SOLID-TIRE FAILURE

At the Left Is an Example of Undercutting Caused by Overloading, One Heavily Overloaded Trip Being Sufficient To Start This Action Which May Continue Even Though the Tire Is Not Subsequently Overloaded. The Blow-Out in the View at the Right Was Caused by Excessive Speed Which Generated Heat within the Tire Faster than the Compound Could Dissipate It, Resulting in Disintegration or Actual Melting of the Compound and the Formation of a Gas That Blows Out through the Tread or Side Wall

pairs of thermocouples were mounted on the surface of the drums.

Three thermocouples were placed under the tire bead which was directly over the brake-drum, and which on a motorcoach would be called the outer bead of the inside tire. Two thermocouples were, as a rule, placed under a bead of the second tire, which corresponds to the inner bead of the outer tire on a motorcoach.

In all tests 6-in. dual tires were mounted on the wheels and run under standard loading and inflation conditions. In tests run to constant brake-drum temperatures, the braking effort was manipulated by a hand screw, holding the brake-drum temperature constant until an equilibrium temperature was reached at the bead directly over the brake-drum. Tests were then repeated, maintaining a constant brake horsepower until a corresponding equilibrium temperature of both drum and bead were attained. The results of both type of test naturally fall on the same curve.

As a result of these tests the authors arrived at the following conclusions:

- (1) The relative cooling-action of the four wheels tested is found to be substantially in the same order as reported in Goodyear and Budd tests conducted under road-service conditions
- (2) Comparison of the four wheels on the basis of constant brake-horsepower shows a wider difference in the same order than comparison on the basis of constant drum-temperature, as was prophesied in the Goodyear report. Comparison on the basis of constant brake-horsepower more nearly reflects the relative value of the wheels in actual service
- (3) The greater the cooling action of a given wheel, the greater apparently is the error in comparing with other wheels on the basis of constant brake-drum temperature and the greater the necessity of a comparison on the basis of constant brake-horsepower
- (4) For the heat-dissipating devices tested, substantially the same relative improvement was noted on all wheels
- (5) The cooling properties of a wheel increase with the speed of rotation for a given brake energy input
- (6) Variations in speed did not materially change the relative cooling-action of the three 20-in. wheels
- (7) Forced ventilation by external fans is indicated as an aid for the dissipation of brake-drum heat. The slower the speed of a motorcoach, the greater should be the effect of forced ventilation
- (8) The tire trouble known as "burned beads" cannot result from "heat due to tire flexing" and must be attributed to brake-drum heat caused by dragging brakes or excessive use of brakes
- (9) Excessive flexing in a tire due to under-inflation, heavy loading or high speed will accentuate the effect of brake-drum heat on the bead by decreasing the temperature gradient between bead and tread

ALL INTERESTS WELL REPRESENTED

The roster of the members and guests attending the Transportation and Service Meeting has been made a part of the story of the meeting as it is believed that without this information it would be impossible for members to appreciate the widely representative character of the attendance at the technical sessions.

Abell, Arthur H.	International Motor Co.
Abell, R.	Single Valve Engine Co.
Adams, L. Herman	Eastern Massachusetts Street Rail- way
Ainsworth, George	Franklin Union
Allen, Bernard	Canadian National Railways

Allen, E. W.
Allen, R. J.
Allison, J. E.

Ammerman, K. J.

Arringdale, L. O.
Aubin, William
Ayer, P. F.

Bachman, B. B.
Bacon, D. L.

Baker, Day
Baker, Harry C.
Baldwin, Harry G.
Ballantine, N. D.
Barringham, R. J.

Bartholomew, J. R.
Baughman, C. R.
Baumgartner, W. J.
Beattie, J. B.
Beauchamp, A. A.
Beckwith, C. F.
Bedford, C. W.
Beedle, H. W.
Beers, W. Warren
Behr, H.
Birmingham, Frank E.

Bird, Paul P.
Bishop, John A.
Bishop, Thomas J.
Bishop, Thomas F.
Blaker, Ernest
Bleecker, John S.
Bleyle, Carl A.
Boardman, H. E.
Bond, Paul
Borton, C. A.
Bourdon, Allen P.

Brackett, D. E.
Brady, Joseph J.
Brand, Charles L.
Brewer, John W.
Brown, Everett A.
Brown, George A.
Brown, Knox T.
Buchanan, F. C.
Buchanan, James A.
Buckendale, L. Ray
Buckley, Charles F.
Buckley, J. J.
Burnett, R. S.
Burr, F. H.

Callahan, W. F.
Carroll, E. L.
Carveth, Harry
Castle, Charles C.

Chandler, William A.

Chappell, B. H.

Church, H. B.
Church, John G.
Clark, E. A.
Clark, Leonard T.
Clark, W. M.
Clarkson, Coker F.
Clo, J. H.
Clodio, P. V.
Clough, Robert M.

White Co.
Boston & Worcester Street Railway
Massachusetts Institute of Tech-
nology
American Car & Foundry Motors
Co.
Hunt-Spiller Mfg. Corporation
Franklin Union
Boston Sand & Gravel Co.

Autocar Co.
New York, New Haven & Hartford
Railroad
Motor Truck Club, Inc.
Dayton Steel Foundry Co.
New Departure Mfg. Co.
Seaboard Air Line Railway
New York, New Haven & Hartford
Railroad

Westinghouse Air Brake Co.
Standard Oil Co. of New Jersey
Garford Motor Truck Co.
Lapeer Trailer Corporation
Harper Hanger Co.
Automotive Industries
B. F. Goodrich Co.
Electric Storage Battery Co.
Gulf Refining Co.
Federal Mutual Insurance Co.
New York, New Haven & Hartford
Railroad

Boston Sand & Gravel Co.
Socony Burner Corporation
Smith & Co.'s Express
Smith & Co.'s Express
B. F. Goodrich Co.
Philadelphia
Texas Co.
Boston
Franklin Union
Autocar Co.
New York, New Haven & Hartford
Railroad

Federal Motor Truck Co.
B. F. Goodrich Rubber Co.
Davis Welding & Mfg. Co.
International Motor Co.
Brown Lipe Gear Co.
Franklin Union
Packard Motor Car Co.
Columbian Steel Tank Co.
Bureau of Public Roads
Timken Detroit Axle Co.
Frank J. Buckley
B. F. Goodrich Rubber Co.
Society of Automotive Engineers
Cleveland Pneumatic Tool Co.

Boston & Albany Railroad
Society of Automotive Engineers
Mayflower Oil Co.
American Car & Foundry Motors
Co.

New York, New Haven & Hartford
Railroad

Mallauf Haulage & Maintenance
Corporation

H. B. Church Truck Service Co.
Boston & Albany Railroad
Budd Wheel Co.
H. S. Macomber & Co., Inc.
S. S. Pierce Co.
Society of Automotive Engineers
A. Schrader's Son, Inc.
Bragg-Kliesrath Corporation
Mayflower Oil Co.

MEETINGS OF THE SOCIETY

531

Cobleigh, H. R.

Coleman, H. B.
Collum, E.Collison, A. F.
Connor, A.
Connors, T. P.
Converse, Herbert L.
Corey, C. H.
Coughlan, John S.
Cowan, E. W.
Cown, Henry W.
Crafts, P. P.
Crandall, Bruce V.
Crawford, J. B.
Crowell, H. C.
Critchley, Don
Curtis, R. W.Daly, W. E.
Darrow, B.National Automobile Chamber of
CommerceHoopes Bro. & Darlington, Inc.
New York, New Haven & Hartford
RailroadInternational Motor Co.
Toronto Hydro-Electric System
Middlesex & Boston Street Railway
Electric Storage Battery Co.
C. G. Spring & Bumper Co.
Firestone Tire & Rubber Co.
Standard Oil Co.
Cown Truck Tire Co.
Mack Motor Truck Co.
Railway Review
Boston & Maine Railroad
Pennsylvania Railroad
Firestone Tire & Rubber Co.
Beacon Oil Co.Gulf Refining Co.
Goodyear Tire & Rubber Co.

Fales, Dean A.

Fannon, H. E.
Farley, P. O.
Farnsworth, S. W.
Faye, Roy A.
Ferrandou, A. H.
Filter, F. R.
Fitch, B. F.
Flynn, C. J.
Foote, J. W.
Fox, George E.
Fox, Leland W.
Freeland, R. H.
Freeman, Frank P.
French, George W., Jr.
Fritch, H. F.
Frost, A. H.
Fuilayan, D.
Fuller, E. L.

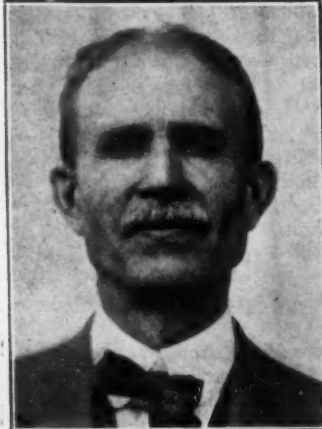
Gillilan, C. S.

Massachusetts Institute of Tech-
nologySix Wheel Co.
Overman Cushion Tire Co.
New York City
Brake Synchometer Co.
Graham Bros.
Standard Oil Co. of New York
Motor Terminals Co.
General Transportation Co.
New York Central Lines
Timken Detroit Axle Co.
Firestone Tire & Rubber Co.
Westinghouse Electric & Mfg. Co.
Public Service Transportation Co.
General Motors Truck Co.
Boston & Maine Railroad
Vacuum Oil Co.
S. S. Pierce Co.
Cadillac Automobile Co. of Boston

Goodyear Tire & Rubber Co.



L. H. Young

Photograph by Bachrach
Howard F. Fritch

E. H. Lockwood



H. D. Hukill

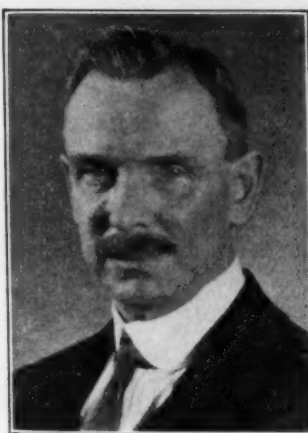
AUTOMOBILE REPAIRING, RAILROADS, EDUCATION, AND AIRBRAKES WERE REPRESENTED BY THESE FOUR ATTENDANTS AT THE TRANSPORTATION
AND SERVICE MEETINGDavis, B. S.
Davis, E. W.
Davis, Francis W.
Davis, H. G.
Davis, L. R.
Davis, William H.
Day, Henry S.
Deaner, L. A.
Dell, G. F.
DePermentier, Paul
Derby, S. F.
Deveney, M. F.
Deveney, Edward J.
Dillon, Capt. L. F.
Dodge, W. C., Jr.
Dodson, C. W.
Donnelly, Martin G.
Dooling, T. H.
Doramajian, Paul
Douglas, Samuel T.
Downing, R. S.
Drake, Charles L.
Duffy, William J.
Dumont, R. Duval
Dunn, Joseph F.Eccleston, Nathan G.
Edmonds, Frank W.
Edmondson, O. L.
Einstein, A. W.
Elliott, Col. J. H.Commonwealth Tire Co.
Westinghouse Air Brake Co.
Waltham, Mass.
Westinghouse Air Spring Co.
United States Rubber Co.
General Motors Truck Co.
Westinghouse Electric & Mfg. Co.
Philadelphia Rubber Co.
Pennsylvania Railroad
Cambridge, Mass.
John J. McCarthy Co.
Perin Walsh Co.
Perin Walsh Co.
Ordnance Department
Ferodo & Asbestos, Inc.
Oakes & Dow Spark Plug Co.
Perin Walsh Co.
Electric Storage Battery Co.
Franklin Union
Gulf Refining Co.
Armour & Co.
SKF Industries, Inc.
Stover Express, Inc.
Fink-Dumont-White, Inc.
Mexican Petroleum CorporationFirestone Tire & Rubber Co.
Terminal Trucking Co.
Fink-Dumont-White Co.
Retail Delivery Association
ChicagoGilman, Frank B.
Godfrey, George B.
Gordon, Charles
Gordon, William R.
Gorman, Frank C.
Gormely, J. V.
Graham, W. J.
Grant, Edward K.
Gregory, LeRoy H.
Grey, E. H.
Groce, Peter J. S.
Gwyn, L. R., Jr.Hadaway, W. S.
Hadlock, E. W.
Haigler, Edmund D.
Hald, Fred C.
Hall, H. A.
Hard, Roger E.
Hardy, F. I.
Harper, William D.
Hatton, A.
Heald, James N.
Hemman, L. D.
Herrick, N. D.
Herrington, A. W.
Hessler, Robert V.
Heywood, C. E.
Hibbeler, Conrad
Hinchliffe, Leonard
Hobbs, F. S.V. A. Nielsen Co.
Reo Motor Car Co.
Electric Railway Journal
Pierce-Arrow Motor Car Co.
Fisk Tire Co., Inc.
Cleveland Pneumatic Tool Co.
Boston & Albany Railroad
Franklin Union
Gulf Refining Co.
Gulf Refining Co.
Franklin Union
American Railway Express Co.Edison Lamp Works
Gulf Refining Co.
Harvard Engineering School
Claybourne, Inc.
C. E. Hall & Sons
Henshaw Motor Co.
Boston & Maine Railroad
Harper Hanger Co.
Canadian Pacific Railway
Heald Machine Co.
Armour & Co.
Boston Edison Co.
City of Washington
Brown Lipe Gear Co.
Society of Automotive Engineers
Mercury Mfg. Co. of Chicago
Motor Coach Guide
New England Transportation Co.

- Holliday, J. R.
Holman, A. W.
Hone, A. C.
Horine, M. C.
Horner, F. C.
Howatt, Robert G.
Howe, Archie J.
Howe, A. Vance
Hughes, Adrian, Jr.
Hukill, H. D.
Hunt, Frank W.
Husted, Elbert E.
- Ingalls, James W.
Ireland, E. W.
- Jay, Frank
- Johnson, A. A.
Johnson, Arthur G.
Johnson, Earl L.
Johnson, Frank E. H.
Johnson, Frederick K.
Jones, G. G.
Joslin, Harley
Joyce, L. V.
- Judson, D. R.
- Kalish, D. F.
Kane, J. F.
Kearney, William G.
Keene, J. H.
Keith, S. H.
Kellett, William P.
Kells, C. F.
- Kennerly, Martin J.
Kimball, S. W.
King, Henry F.
- Kirkwood, M. W.
Klauser, Paul B.
Koess, Ralph H.
Kreuder, A. H.
- Lake, C. S.
Langley, J. Arthur
Larrabee, A. S.
Lawrie, Robert
Leary, J. A.
- Lennon, John M.
Lewis, E. A.
Lindall, John
Linforth, John M.
Littlefield, Charles E.
- Lockwood, E. H.
Lodge, Albert
Lohman, R. W.
Loomis, Edward F.
- Lord, Charles K.
Loveless, W. F.
Lowe, Edward F.
Lybeck, R. F.
Lyne, James G.
Lyon, Charles S.
- Maerz, John F.
Magee, Richard A.
Malkin, Ewing
Manley, E. D.
Manly, Charles M.
Mansur, C. W.
Manuel, F. A.
- White Co.
Western Transportation Co.
White Co.
International Motor Co.
General Motors Corporation
Pierce-Arrow Sales Co.
Morton Co.
Westinghouse Air Brake Co.
United Railways & Electric Co.
Westinghouse Air Brake Co.
Trailmobile Co.
Titeflex Metal Hose Co.
- Northeastern University
Franklin Union
- American Car & Foundry Motors Co.
General Motors Truck Co.
Mack Motor Truck Co.
Franklin Union
Noyes Buick Co.
Mack Trucks, Inc.
Lapeer Trailer Corporation
Goodyear Tire & Rubber Co.
American Car & Foundry Motors Co.
Dwight R. Judson Co.
- Spicer Mfg. Co.
Batchelder Bros., Inc.
B. F. Goodrich Co.
Mack Motor Truck Co.
Fruehauf Trailer Co.
Brantford, Ont., Canada
American Water Works & Electric Co.
Middlesex & Boston Railway
Mack Motor Truck Co.
Massachusetts Institute of Technology
Canadian Pacific Transport Co.
Klauser Bros.
J. W. Robinson Co.
Indian Refining Co.
- Chesapeake & Ohio Railway Co.
H. S. Macomber & Co.
Boston & Maine Transportation Co.
Franklin Union
Delaware, Lackawanna & Western Railroad Co.
E. P. Winwan & Son
Consolidated Trucking Co.
Boston Elevated Railway
Goodyear Tire & Rubber Co.
Massachusetts Institute of Technology
Yale University
E. A. Patch Co.
Electrical Products Corporation
National Automobile Chamber of Commerce
International Motor Co.
Boston
K. P. Products Co.
Beacon Oil Co.
Simmons Boardman Publishing Co.
Motor Haulage Garage & Shop Corporation
Stanley Works
Texas Co.
Malkin Motor Freight Co.
Firestone Tire & Rubber Co.
New York City
General Electric Co.
Franklin Union
- Martell, E. F.
Martin, G. H.
Maynard, W. A.
Maynard, W. A.
McCall, George
McCutcheon, William A.
McGlone, Harry F.
McLaughlin, John
McLean, Walter C.
McNeillie, J. K.
Metz, Albert G.
Middlekauf, E. B.
Middleworth, H. O.
Milburn, S. R.
Mildrum, W. J.
Mills, Stanley W.
Moore, F. T.
Morrison, W. H.
Morton, H. E.
Mutz, Guy W.
Moyer, James A.
Moynihan, C. J.
Muther, W. P.
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- Nazro, H. F.
Neale, Fred
Nesmith, R. H.
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- Nielsen, V. A.
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Nordberg, Carl A.
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Nourse, F. O.
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- O'Brien, George H.
O'Connor, Pat E.
Ofensend, C. F.
Ogilvie, Victor J.
Olson, C. T.
Orth, A.
- Ortla, F. L.
Osterman, Lester A.
- Palmer, Robert W.
Paquette, J. A.
Park, Charles F.
- Parker, F. L.
Pearl, E. B.
- Pearson, C. L.
Peavey, H. F.
Perin, Donald W.
Perkins, D. W.
Peterson, George
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- Philbrick, J. W.
Piroomoff, George S.
Plimpton, R. E.
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Preble, T. L.
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Prior, R. H.
Putnam, A. L.
- Ramsdell, Chester
Raux, M. E.
Raymond, W. H.
Read, Clarence E.
Reed, J. A.
- B. F. Goodrich Rubber Co.
Westinghouse Air Brake Co.
Mack Motor Truck Co.
White Co.
International Motor Co.
West Penn Power Co.
General Motors Corporation
Franklin Union
Mack Motor Truck Co.
Delaware & Hudson Railroad Co.
Chilton-Class Journal Co.
Texas Co.
Consolidated Gas Co.
B. F. Goodrich Rubber Co.
Pierce-Arrow Motor Car Co.
Pierce-Arrow Motor Car Co.
B. F. Goodrich Rubber Co.
Lehigh Valley Railroad
B. F. Sturtevant Co.
Society of Automotive Engineers
Commonwealth of Massachusetts
W. Filene Sons Co.
Muther Mfg. Co.
Chassis Lubricating Co., Inc.
- General Motors Truck Co.
Christensen Air Brake Co.
Morgan & Wright Co.
Lehigh Valley Railroad
Franklin Union
New York, New Haven & Hartford Railroad
V. A. Nielson & Co.
Lee Tire & Rubber Co.
Franklin Union
Maxim Motor Co.
Gruss Air Spring Co.
General Transport Co.
- G. H. O'Brien Transportation Co.
General Motors Truck Co.
Miller Rubber Co.
Massachusetts Automobile Club
Strom Bearings Co.
General Motors Corporation, Research Laboratories
Dorchester, Mass.
General Motors Truck Co.
- Joseph Palmer
Laconia Car Co.
Massachusetts Institute of Technology
United States Rubber Co.
New York, New Haven & Hartford Railroad
Goodyear Tire & Rubber Co.
Springfield, Mass.
Perin Walsh Co.
International Motor Co.
Dunlop Tire & Rubber Co.
Massachusetts Institute of Technology
B. F. Goodrich Rubber Co.
White Co.
Bus Transportation
National Railway Appliance Co.
White Co.
Goodyear Tire & Rubber Co.
Massachusetts Motor Trucking Co.
Multibestos Co.
- Harper Hanger Co.
S. S. Pierce Co.
Armour & Co.
J. W. Robinson Co.
B. F. Goodrich Rubber Co.

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 Rinehart, C. R.
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 Rohn, A.
 Rouillard, Edwin H.
 Russell, A. P.
- Sanford, R. S.
 Scaife, A. J.
 Scarr, F. J.
 Schoff, A. L.
 Schulz, A. C.
 Scragg, George H.
 Shaw, K. A.
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 Shields, J. W.
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 Siefert, C. H.
 Sloan, John A.
 Smith, Charles F.
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 Smith, G. W., Jr.
 Smith, T. C.
- Smith, W. P.
 Sneddon, A. M.
 Snider, Henry J.
 Sparrell, L. Warren
 Speed, Fred H.
 Spofford, Harry
- Stahl, J. K.
 Stebbins, C. B.
 Steinberger, M. F.
 Stephenson, Paul L.
 Stinges, D. A.
 Stocks, C. W.
 Stone, C. W.
 Stone, M. I.
 Stults, J. V. N.
 Sullivan, J. T.
 Swentzel, F. J.
 Swift, M. C.
- Sylvester, Joseph P.
- Taver, H. G.
 Travers, Arthur
 Travers, James A.
 Taylor, G. E.
 Templin, E. W.
 Thee, Lieut. Walter C.
 Thompson, Stephen G.
 Thorne, Louis
 Tibbetts, F. C.
 Timothy, H. W.
- Ufford, Charles A.
 Underwood, A. J.
 Underwood, Arthur F.
- VanNess, R. H.
 Veal, C. B.
 Voselovitch, Michael
- Waerner, T. A.
 Waid, P. C.
 Wallace, Charles
 Walrath, P.
 Walsh, J. H.
 Waters, R. A.
 Wheeler, E. O.
- Ferodo & Asbestos, Inc.
 National Railway Appliance Co.
 Boston & Albany Railroad
 Boston & Maine Railroad
 Reo Motor Car Co.
 Overman Cushion Tire Co.
 International Motor Co.
 Westinghouse Air Brake Co.
Motor Service Bulletin
 Franklin Union
 New England Transportation Co.
- Bendix Brake Co.
 White Co.
 Pennsylvania Railroad
 Overman Cushion Tire Co.
 Bragg-Kliesrath Corporation
 International Motor Co.
 Westinghouse Electric & Mfg. Co.
 Chilton-Class Journal Co.
 Firestone Tire & Rubber Co.
 Pennsylvania Railroad
 Mexican Petroleum Corporation
 General Motors Truck Co.
 Mack Motor Truck Co.
 Edison Electric Illuminating Co.
 Beaver Valley Motor Coach Co.
 White Co.
 American Telephone & Telegraph Co.
- General Motors Corporation
 Firestone Tire & Rubber Co.
 Mack Motor Truck Co.
 Franklin Union
 E. A. Patch Co.
 Copper & Brass Research Association
 Strom Bearings Co.
 Waukesha Motor Co.
 Baltimore & Ohio Railroad
 Franklin Union
 Mack Motor Truck Co.
Bus Transportation
 Stone Express, Inc.
 General Motors Truck Co.
 Perin Walsh Co.
Boston Globe
 New England Transportation Co.
 Massachusetts Institute of Technology
 Lee Tire & Rubber Co.
- Mack Motor Truck Co.
 B. F. Goodrich Rubber Co.
 Boston
 Mack Motor Truck Co.
 Six Wheel Co.
 United States Army
 Stone-Thompson Co.
 Franklin Union
 Sootless Spark Plug Co.
 Vacuum Oil Co.
- Ufford Dress Form Co.
 Society of Automotive Engineers
 Massachusetts Institute of Technology
- Town of Montclair
 Society of Automotive Engineers
 Franklin Union
- Tidewater Oil Co.
 Standard Oil Co. of New Jersey
 Franklin Union
 Standard Oil Co. of New Jersey
 Middlesex & Boston Street Railway
 Chase Companies, Inc.
 Pilgrim Laundry Co.



H. W. Cowan
 TWO STANDARD OIL CO. REPRESENTATIVES



White, L. C.
 White, T. P.
 Whitfield, Ernest O.

Whitham, Glenn S.
 Whittemore, F. B.
 Whittelsey, C. B., Jr.
 Wilde, Elton S.
 Willink, Arthur

Wilson, G. Lloyd
 Winchester, F. U.
 Winchester, J. F.
 Wiswell, A. B.
 Wolfard, M. R.
 Wood, Henry M.
 Wood, M. A.
 Woodberry, Ronald S.
 Woodstock, K.
 Woolaver, Harry B.

Yeo, George E.
 Young, Linwood H.

General Motors Truck Co.
 Federal Motor Truck Sales Co.
 New York, New Haven & Hartford Railroad
 Charles Street Garage Co.
 Mack Trucks, Inc.
 Society of Automotive Engineers
 Union Street Railway Co.
 Massachusetts Institute of Technology
 University of Pennsylvania
 Motor Wheel Corporation
 Standard Oil Co. of New Jersey
 Whiting Milk Co.
 Hopewell Bros.
 Trailmobile Co.
 International Harvester Co.
 Freight Container Service Co.
 Aetna Life Insurance Co.
 Mack Motor Truck Co.

Middlesex & Boston Street Railway
 Linwood H. Young Co.

SUCCESS DUE TO LOCAL COMMITTEES

Every Detail Taken Care of by Committees
 Appointed by New England Section

At the Motorcoach and Truck Operation Session which was held on the morning of Nov. 18, Chairman A. J. Scaife stated that the success of the meeting was largely attributable to



SOME OF THE MEMBERS OF THE LOCAL RECEPTION COMMITTEE
 In the Rear Row from Left to Right are F. W. Davis; M. R. Wolfard, chairman; H. E. Morton; and R. E. Northway. The Two Members in the Front Row are V. J. Ogilvie (at the Left) and E. O. Wheeler (at the Right)

the keen interest and untiring effort of the members of the New England Section who had given up their time to take care of the endless number of details that go to make up the success of any meeting, and in appreciation of their work the members gave the New England Section Committees a rising vote of thanks.

The Committee responsible for the general character of the Transportation and Service Meeting was under the chairmanship of J. F. Winchester, the photographs of the members of this committee appearing on the opposite page. To handle the large number of detail problems involved, special committees composed of New England Section members located in Boston were appointed. These committees were as follows:

RECEPTION COMMITTEE

M. R. Wolfard, *Chairman*

F. W. Davis
D. R. Judson
H. E. Morton
R. E. Northway

V. J. Ogilvie
M. Olley
C. F. Park
E. O. Wheeler

ENTERTAINMENT COMMITTEE

V. A. Nielsen, *Chairman*

E. L. Fuller

Albert Lodge

L. H. Young

INSPECTION COMMITTEE

W. M. Clark, *Chairman*

S. T. Douglas
D. A. Fales

F. R. Filter
F. E. H. Johnson

V. A. Nielsen

COOPERATIVE COMMITTEE

Day Baker, *Chairman*

Albert Lodge

V. A. Nielsen

PUBLICITY COMMITTEE

J. A. Moyer, *Chairman*

Albert Lodge

L. H. Young

The Inspection Committee deserves special mention in connection with the leaflet that it distributed to the members and guests making the inspection trip, these leaflets giving a short description of the various points of historic interest passed on the trip, together with short descriptions of the maintenance plant of the Standard Oil Co. in East Cambridge and the Massachusetts Institute of Technology. Prof. D. A. Fales, of Massachusetts Institute of Technology, and C. B. Jones and F. R. Filter, of the New England Division of the Standard Oil Co. of New York, deserve special credit for the admirable way in which they conducted the trip.

At the 1925 Transportation Meeting the Pennsylvania Section presented the members and guests at the Banquet with leather-covered reminder books. This year the New England Section presented the members with automatic pencils which were keenly appreciated by the holders of the

reminder books as well as the members who attended the Transportation and Service Meeting for the first time.

It is needless to say that the Boston meeting could not have been a success without the large amount of study and work by the authors of the many papers presented at the technical sessions and the interest of the Session chairmen.

An innovation that deserves special mention was the playing of the Orthophonic Victrola in the meeting-room for the 30 min. immediately preceding each of the five technical sessions. Members found it more pleasant to go into the meeting room and listen to the music while awaiting the opening of a session than to linger in the hallway until the sound of the chairman's gavel reminded them that they should be on their way. Anyone who has ever tried to persuade an audience to enter a meeting-room more than 3 sec. in advance of the opening-time will appreciate that this was no mean feat. Credit is due to John Warner, formerly the Society's Meetings Manager and now with the Studebaker Corporation of America, for having originated this idea. An interesting feature was the distribution of programs announcing the musical selections that were to be played.

DINNER ON JAN. 13 AT HOTEL ASTOR

Annual Meeting Starts on Jan. 25 at Detroit and Ends with Carnival on Jan. 28

Certain annual Society events need no introduction to the members. They run true to form each year and their omission would upset the automotive calendar. The two most outstanding of these events are the Annual Dinner and the Carnival.

This year the Annual Dinner comes on Jan. 13, being the outstanding event of Automobile Show Week. New York City will welcome the members in its accustomed way, and members will do well to reserve their rooms and theatre seats well in advance if they do not desire to be mentioned in the vernacular of Wall Street. The program for the Annual Dinner has not been announced by H. O. K. Meister, but members are assured that this event will go down in the annals of Society history as another memorable occasion. The plans for the 1927 Carnival, which will be held as usual at the Oriole Terrace, are rapidly taking form under the management of E. V. Rippingille, chairman of the Carnival Committee, and the members of his committee. Several meetings have been held and if present plans are carried through the attendance will be limited to the capacity of the dance floor, which in past years has been overcrowded during the early hours of the night. As soon as it is possible to accept reservations for the Carnival, an announcement will be sent to all members of the Society. As this event comes on the last day of the Annual Meeting, it will serve as a fitting climax to the technical sessions that are being arranged from Jan. 25 to 28 inclusive.

The Meetings Committee has arranged for technical sessions covering the subjects of Training, Production, Brakes, Light Cars, Transmissions, Research, Bodies, Chassis, Engines, and Detonation. In addition, a Mystery Session has been scheduled, the details of which will not be given out before the meeting.

NATIONAL MEETINGS CALENDAR

ANNUAL DINNER—Hotel Astor, New York City—Jan. 13, 1927

ANNUAL MEETING—General Motors Building, Detroit—Jan. 25 to 28, 1927

THE CARNIVAL—Oriole Terrace, Detroit—Jan. 28, 1927



V. A. NIELSEN



H. R. COBLEIGH



F. E. H. JOHNSON



R. E. PLIMPTON



F. J. SCARR



G. S. WHITHAM



A. J. SCAIFE



A. W. HERRINGTON



J. F. WINCHESTER



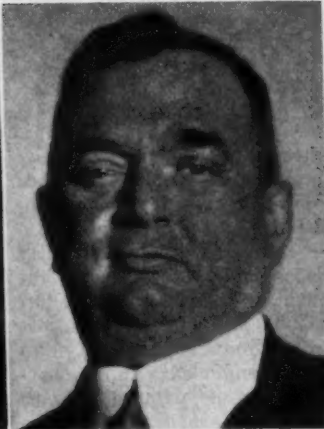
L. H. PALMER



F. C. HORNER



C. O. GUERNSEY



A. F. MASURY



E. W. TEMPLIN

FOUR-SPEED TRANSMISSIONS COMING

One of the most interesting papers of the Annual Meeting will be on four-speed transmissions for passenger-car applications. The research that has formed the basis for this paper indicates that a saving in gasoline consumption of 20 per cent at ordinary touring speeds can be obtained by the use of four-speed transmission geared direct on fourth-speed. With the type of transmission developed by the authors, shifting from fourth to third or from third to fourth at speeds as high as 50 m.p.h. without any difficulty is possible, as well as shifting without throwing out the clutch.

An English engineer of prominence is also expected to present a paper at the Annual Meeting dealing with the English light car. At this time the name of the engineer who will present this paper cannot be announced, but the first *Meetings Bulletin* covering the Annual Meeting, which will be mailed to the members during December, will contain this information.

Strange to say, brakes still squeak and are demanding

considerable attention from engineers. The Brake Session will include several papers covering braking requirements, problems of pivoting, brake-lining tests, and special types of braking mechanisms. The Detonation Session will be in the form of a symposium, several papers already having been accepted by the Meetings Committee covering the chemical analysis and anti-knock values of gasolines, detonation specifications, detonation characteristics, methods of measuring detonation, and the causes and effects of detonation.

Manufacturers are still experiencing difficulty with front wheels owing to the effect of steering, balloon tires and four-wheel brakes. The Chassis and Engine Session will include a paper by a recognized authority on pitch, toe-in and caster that will go a great way in stating the fundamentals of this problem.

Definite information with regard to the subjects and authors will be published in a later *Meetings Bulletin*, which will reach the members shortly before Christmas.

SECTIONS MEETINGS IN NOVEMBER

INTERURBAN MOTORCOACH MAINTENANCE

Milwaukee Section Is Told of Company's Methods and Inspects Installation

As an interesting departure from the usual monthly meeting, the Milwaukee Section combined its technical session on the evening of Nov. 3 with an inspection of the garage, shop and maintenance methods in the transportation building of the Milwaukee Electric Railway & Light Co., in the assembly hall of which the meeting was held. The members were the guests for the evening of the Company and were welcomed by John H. Lucas, superintendent of rolling-stock, and listened to and discussed a paper on motorcoach maintenance presented by Henry L. Debbink, superintendent of gasoline vehicles. W. S. Nathan, chairman of the Section, presided at the technical meeting.

Prior to the delivery of Mr. Debbink's paper the meeting elected Mr. Nathan to represent the Section on the Sections Committee of the Society next year and Fred M. Young as alternate. It also elected as a nominating committee for the selection of Section officers for election next spring the following five members: John J. Balsom, A. D. Chandler, Cyrus L. Cole, Henry L. Debbink, and J. B. Fisher.

Chairman Nathan then said that the Governing Committee had met earlier in the evening and heard plans for meetings to be held during the winter and spring, on which Mr. Young had worked diligently during the summer and fall. The December meeting, he said, is to be in the nature of a surprise, as a new development not yet revealed will be described fully. Some excellent plans are also in mind for meetings after the first of the year.

HOW MOTORCOACH FLEET IS MAINTAINED

City and interurban motorcoaches have been operated by the street railway and light company of Milwaukee since the summer of 1919, said Mr. Debbink in his address. Automobiles and motor-trucks have been operated by it for a considerably longer period. The fleet has grown steadily until now it includes 175 automobiles and motor-trucks that make about 100,000 miles a month and 141 motorcoaches whose monthly mileage is close to 400,000. This high motorcoach mileage presents different maintenance problems than confronted the company with its passenger-car and motor-truck equipment. Periodic inspections come around four to five times as often and maintenance operations that are rare on motor-trucks must be performed regularly on the motorcoaches.

The modern motorcoach must be able to run from 40,000 to 60,000 miles annually for 4 or 5 years at a reasonable operating cost. To prevent road delays so far as possible and still keep maintenance costs reasonable, many changes in maintenance methods were necessary from time to time. Mr. Debbink reviewed these changes from 1920, when a system of weekly inspections at mileage intervals of 700 to 1000 was started, until now.

Under the present system the oil is drained from the crankcase after each 1000 miles, the chassis is greased and those parts that give most frequent trouble are inspected. This inspection is made between runs or at night and can be completed by a mechanic and a helper in 45 min. A general inspection is given after each 4000 miles and a general overhaul of chassis and body at intervals averaging 30,000 miles. Overhaul of the chassis requires from 3 to 6 days and the body overhaul and painting from 5 to 7 days. In general the four-cylinder engines are changed at every other overhaul, or between 50,000 and 60,000 miles. The newer six-cylinder engines give indications that they will need to be changed at the third and in some cases at the fourth overhaul. The speaker specified briefly what work is done in the overhauls.

SPECIAL FACILITIES SPEED THE WORK

Some special maintenance facilities of interest, said Mr. Debbink, include a pit for the 1000-miles inspection. This has a two-level floor for convenience in working on motorcoaches of different chassis levels, is provided with a grease pressure-line so that a nozzle can be applied to all the Alemite fittings and grease fed to them as long as a trigger is pressed and has a funnel into which crankcase oil is drained and from which it flows to an underground tank, whence it is drawn by an electrically-driven pump to an oil reclaimer.

Another distinctive device is a spray washing-rack upon which the motorcoaches are driven and washed. A crew of four men washes three times as many vehicles per day as six washers did previously.

A third piece of equipment is a floor-type dynamometer designed to use two old street-car motors. With this dynamometer the coaches can be given road tests without leaving the garage and engines can be run-in after they have been overhauled without being removed from the chassis.

More than 800,000 gal. of gasoline and 30,000 gal. of lubricating-oil are used per year. The gasoline is bought in tank-car quantities and storage facilities for 1,000,000 gal. are provided so that the fuel can be bought when the price is low and stored for use when it is high.

DISCUSSION TOUCHES ON MANY TOPICS

Much interested discussion followed the conclusion of the paper and the author and Mr. Lucas answered numerous questions asked by F. M. Young, W. S. Nathan, E. A. Cousins, A. C. Wollensak, DeWitt Clausen, and Lloyd M. Kanters pertaining to standardization of the type of vehicles used, why some operating companies build their own motorcoaches, experience of the Milwaukee company with the steam-cooling system and its use for heating the vehicles, relative desirability of four and six-cylinder engines, experience with oil-filters, the quality of reclaimed oil, the trouble-record system on unit parts, comparison of street-car and motorcoach operation, and the attitude of the company toward adoption of the gasoline-electric drive.

SURPRISES SPRUNG AT DETROIT

Talk on Research Followed by Motion Pictures of Detroit Arctic Expedition

Features that made the meeting of the Detroit Section on the evening of Nov. 4 more than usually interesting were a talk by C. F. Kettering on the broad phases of scientific research and their relation to engineering, which was given in the speaker's customary epigrammatic style; the showing for the first time of six reels of motion pictures of the Detroit Arctic Expedition in airplanes by Captain Wilkins; and the presence of President Thomas J. Little, Jr., of the Society, and presidential nominee J. H. Hunt, both of whom spoke briefly.

The meeting was held in the General Motors Building, where 175 members sat down to dinner together and enjoyed a surprise entertainment feature. Similar surprises were promised for future meetings. Nearly 300 attended the meeting that followed and over which Walter T. Fishleigh, chairman of the Section, presided.

MUST KEEP PEOPLE DISSATISFIED

In concluding his extemporaneous talk, in which he told of research work in various fields, Mr. Kettering asserted

The great work of an engineer is to keep people healthily dissatisfied with what they have. If we realize that, we can go along advancing intellectually. We are perhaps in the greatest age of development of the automotive industry and are developing all the phases of engineering to a high degree. The engineer has assumed a position in the world such as he never had before. Economists are asking, "What is the future of our business?" My advice to engineers is to know more about the technical end of their business. The important thing is to recognize the relation of what they are doing to the economics of their business. Today we are just beginning to measure the great phenomena of nature. How long can this development go on? Until we know all the phenomena.

He told of the development of the nickel-iron submarine cable by which messages are now transmitted between America and England at from 8 to 10 times the usual speed, the recently announced development of the cathode-ray tube, the production of methanol and synthol alcohols from coal, and the development of the mercury-vapor turbine for the generation of electric current.

Cathode rays provide a means for further advance in the study of the physical nature of materials, suggested Mr.



C. F. KETTERING

Kettering. The liquefaction of coal is a great advance in organic chemistry and will have much to do with conservation of our natural resources. In this connection the speaker said:

At a meeting of the Conservation Commission one man made a report that our fuels will be exhausted in 8 years; another that they would be exhausted in 125 years. I do not know that we need to worry. I think it altogether possible that we can increase the efficiency of the automobile engine to at least twice what it is today. Enough energy is contained in 1 gal. of gasoline to drive a light car from Detroit to St. Louis, but the average user gets somewhat less mileage than that; he usually wastes 97 per cent of the fuel. We should get at least the banker's rate of interest on the investment. The efficiency of the mercury-vapor turbine is almost double that of the usual steam plant. All lines are stepping up the old ground-rules that are used in the industries.

If given the best information, the man in the shop will utilize it to nearly 100 per cent and get results that surprise even the most efficient. If we could eliminate sulphur, phosphorus, or silica from steel we could produce a better article.

Mr. Kettering then spoke of the economic phases of the continued rapid improvement and increasing production of motor vehicles and said that the great factor in American prosperity is that engineering research has enabled us to convert a greater quantity of materials per man-hour into useful articles than ever before, the improvements create increased demand which keeps capital flowing and labor employed and the American workman can have any article in the Country by the expenditure of from one-fourth to one-tenth the time in his own work that the foreign workman must spend.

DETROIT POLAR EXPEDITION PICTURED

Before the pictures of the Arctic Expedition were shown, Carl B. Fritsche, manager of the Aircraft Development Corporation, explained that this was their initial showing, the ground pictures were taken by Pathé and the air pictures by Captain Wilkins and Major Lanphier. The purpose of the expedition was to establish at Point Barrow, Alaska, a base for exploration of the unknown region between Alaska and Siberia, and despite delays in the transportation of gasoline, the undertaking was a success if for no other reason than because it proved that the Endicott Mountain range is 8000 instead of 5000 ft. high, which is important because the range lies across the shortest air route to the Orient.

Captain Wilkins commented on the pictures as they were shown, saying that both the single and triple-engine airplanes were wrecked within 24 hr. in the first attempt to reach Point Barrow but that subsequently 3500 lb. was carried in the larger craft, which covered 850 miles without stop; three trips were made across the Endicott range carrying extra fuel each time; and 650 gal. of fuel was landed at Point Barrow but this was not enough for exploration with the three-engine airplane and the flying season in the Arctic was over by that time.

METROPOLITAN SCORES A BEAT

Members Hear Design Details of New Burt-McCollum Sleeve-Valve Engine

For the first time the design details of the single-sleeve-valve engine of the Argyll type developed by the Continental Motors Corporation were confided to persons outside that organization when a paper on this new powerplant was read before the Metropolitan Section at its meeting on Nov. 15. Partly due to the interest of the subject and partly to the intense membership campaign being waged by the Section, an unusually large attendance was reached; 186 persons

were present at the dinner, and over 200 were in the audience that listened to the reading of the paper.

At a short business meeting preceding the technical session F. K. Glynn, chairman of the Section, was elected representative to the Sections Committee of the Society. The following were elected as members of the Section's Nominating Committee: William E. Kemp, chairman; A. D. T. Libby; R. E. Plimpton; F. E. Queeney; and C. B. Veal.

W. A. Frederick, chief engineer of the Continental Motors Corporation, prepared the paper of the evening. It was presented by L. P. Kalb, also of the Continental Motors engineering department, while the discussion was presided over by A. M. Niven, his colleague, whose close connection with the development of the engine enabled him to answer adequately the questions and discuss the points raised by members of the audience. G. A. Round, chairman of the meeting, explained, in introducing the speakers and the topic, that the engine will be shown to the public for the first time at the automobile show in January; however, models were exhibited at the meeting, and many members took advantage of the opportunity to familiarize themselves with the operation of the engine and particularly the sleeve-actuating mechanism.

INTERESTING MECHANISM ACTUATES THE SLEEVES

Of particular interest was the section of the paper dealing with this mechanism. The valve-shaft is below the sleeves and at one side, its axis lying parallel to that of the crankshaft. It is driven at engine-speed by chain or gear-train from the crankshaft and has a worm-gear situated at the center line of each cylinder. At the foot of each cylinder and at right angles to the axis of the crankshaft lies the sleeve shaft, consisting of a single cranked shaft and worm-wheel mounted on suitable bearings within the crankcase. The worm-wheel meshes with the valve-shaft worm-gear and rotates at one-half engine-speed. A universal coupling or ball-and-socket connection is placed within a housing provided at the foot of the sleeve-valve while the sphere zone is free to rotate and slide on the sleeve-shaft crankpin that engages in the bore of this member. Rotation of the sleeve shaft imparts a partly rotating and a partly reciprocating movement.

Brief descriptions were given of the valve-actuating mechanisms of other single-sleeve-valve engines, and the history of the Burt-McCollum patents, up to their acquisition last year by the Continental Motors Corporation, was traced. The mechanical features of the engine were presented, particular attention being paid to the detachable cylinder-heads; the cone-frustrum type combustion-chambers; the material, design and timing of the sleeve-valves; and the size and shape of the ports.

In the lively discussion that followed the paper, some participants were H. M. Crane, E. R. Hewitt, H. D. Church,

Joseph Anglada, P. M. Heldt, S. W. Sparrow, and E. W. Templin. Has the poppet-valve engine reached its limitations in respect to the pressures and speed it can achieve, and will it be replaced by the single-sleeve-valve engine in the trend toward greater output? Is the Argyll-type Continental product just another new and interesting engine? Or has the sleeve-valve engine disadvantages such as a heavy and complex valve-actuating mechanism which outweigh the advantages claimed of sustained operating efficiency, good power output and silence in operation? Is the poppet valve the best for fuel feed and exhaust outlet, lacking only in research and refinement of design to make it supreme? These questions propounded in the discussion indicate that the new engine has again focussed attention on an old problem. The effect of the promotion in this Country of the Burt-McCollum engine on the development of the internal-combustion engine will be closely watched.

DETROIT SECTION STUDIES "SHIMMY"

Data on Oscillation Effects with Low-Pressure-Tire Equipment Discussed

Oscillation of the front wheels and axle accompanied by deformation of the tires, which produces an unpleasant effect on the steering of certain motor-cars equipped with low-pressure or so-called "comfort" or balloon tires, is the kind of "shimmy" analyzed in the paper by E. Druesne, of the Michelin Tire Co., presented at the meeting of the Detroit Section that was held on Nov. 18. The phenomenon analyzed is distinct from so-called "pre-War shimmy," which was a kind of slow wobble due to various causes such as defective design of the steering-mechanism, convergency of wheels, unbalanced wheels, and the like and should not be confused with reactions on the steering-wheel arising from unevenness of the ground which are more or less severe in proportion to the sensitiveness of the steering-wheel and the low pressure of the tires. Some of the important features of the paper are appended.

TESTS MADE ON THE 12-HP. 1923 RENAULT CAR

Many factors have an influence on the setting up, maintenance and disappearance of the type of shimmy that was investigated. All these factors are not yet known but the most important ones were considered; that is, the road, the tires, the springs, the steering-mechanism, and the speed. The tests made by the Michelin Company were intended to determine the part played by each of these factors and, to that end, one of the factors was caused to vary, by acting alternately on its constituent elements while the other factors were left undisturbed, or several factors were caused to vary

SCHEDULE OF SECTIONS MEETINGS

DECEMBER

- 1—MILWAUKEE SECTION—Diesel Engines—F. P. Grutzner
- 2—DETROIT SECTION—X-Ray Examination of Metals at the Watertown Arsenal—Col. T. C. Dickson
- 7—BUFFALO SECTION—Recent Aircraft Engine Developments—Lieut. C. C. Champion
- 9—WASHINGTON SECTION—Motorcoach Operation in the City of Washington—Edward Pardoe; Riding Habits and Personal Demands of Motorcoach Passengers—E. D. Merrill
- INDIANA SECTION—Advantages of All-Steel Body—Edward J. Baisley; Advantages of the Fabric Body—H. Steinbrugge. The discussion will be led by a representative of the Rex Mfg. Co.
- 10—SOUTHERN CALIFORNIA—The Latest Development in Aeronautics—Donald W. Douglas and W. P. Kinner
- 14—PENNSYLVANIA SECTION—What's Going On in Philadelphia—A series of 10-min. talks by eight local automotive engineers
- CHICAGO SECTION—Commercial Aviation—William P. MacCracken, Jr.
- 16—METROPOLITAN SECTION—Maintenance, Operation and Service—John Stilwell and T. L. Preble. J. F. Winchester will summarize and lead the discussion
- 18—DETROIT SECTION

simultaneously. Most of the tests were made on a single type of car, a 12-hp. 1923 Renault. While they have not as yet provided a satisfactory explanation of the phenomena considered or the discovery of any simple means of preventing shimmy in all types of car, they were enlightening as to the probable causes of wobble, which, in the order of their importance, are as follows:

- (1) Lateral instability of low-pressure tires that facilitates rolling movement and is the starting point of wobble
- (2) The greater capacity of low-pressure tires for storing and giving back energy, as compared with high-pressure tires
- (3) The reversibility of the steering-gear and the connection of the front wheels by an elastic mechanism, levers and tie-rod, which helps to maintain and to amplify the oscillations

Numerous road-tests were made at different times. An electro-magnetic apparatus was utilized to register the oscillations of the front wheels and axle, and a disc on which a continuous curve was recorded, actuated by clockwork and making one revolution every 7 sec., was used also. Each revolution of the front wheel was recorded on the disc, the circuit being closed by a contact finger mounted on the wheel. A moving-picture camera taking 150 to 200 pictures per sec. was also employed to register the phenomena. The apparatus can be mounted either on the car chassis or at the rear of a car that tows the car under test. The 12-hp. Renault car tested was equipped front and rear with 160 x 860-mm. (6.30 x 33.89-in.) "comfort" tires, inflated to a pressure of 1½ kg. per sq. cm. (21 1/3 lb. per sq. in.), and the tests enabled the drawing of the following conclusions:

- (1) Shimmying takes place on an even dry surface at a "critical" speed of 80 to 85 km. per hr., (49.7 to 52.8 m.p.h.)
- (2) Shimmying is composed of two principal motions, (a) and (b), having the same periodicity of 1/10 to 1/12 sec. but separated as to time by 0.02 to 0.03 sec. Motion (a) is the wobbling or oscillation of the front wheels around their pivoting axes, during which the wheels, the levers and the tie-rod, as a whole, play the part of a pair of scales in which the beam is represented by the tie-rod, the knife-edges by the king-pins and the scale by the wheels. Motion (b) is the "bouncing" or oscillation of the front axle around an axis from front to rear during which one of the tires strikes the ground, deforming itself inwardly, while the other tire has a tendency to leave the ground. In motion (b), there seems to be resonance between the vibration period of the tire and that of the springs, but it has not yet been possible to prove this
- (3) When shimmying sets in, the chassis is shaken violently and the hood appears to be displaced rapidly to the right and to the left. Wobbling sometimes attains such a degree of intensity that, due to the semi-reversibility of the steering-gear, the motion is transmitted by repercussion to the steering-wheel. The extent of the motion is small at the start but increases rapidly and, where the ground is favorable to it, that is, where unevenness does not destroy the synchronism, it sometimes reaches a point that endangers the steering-gear
- (4) The period generally is equal to that of one turn of the wheel. It is not known why. It was thought that it might be due to abnormal points in the tire or the inner-tube, such as the valve or the splice, or to lack of balance in the wheel; but tests made with inner-tubes having two and three valves and three splices,

and wheels balanced statically, still showed wobble to exist, the period remaining the same

- (5) The motion resulting from principal motions (a) and (b) is a true "tramping" motion, the wheel describing a sinusoid on either side of a straight line. The maximum release of the left spring takes place when the left wheel describes the arc situated near the center line of the car. At the same time, the right wheel tends to leave the ground, flattening out the right spring and describing the sinusoidal arc outside the car
- (6) The total oscillation of the axle varies between 12 and 15 deg. The maximum compression of the spring reaches between 40 and 50 mm. (1.57 and 1.97 in.), corresponding to a force of from 400 to 600 kg. (882 to 1323 lb.). The recovery motion of the spring reaches 50 mm. (1.97 in.)
- (7) If it is considered that the compressions and recoveries succeed one another at the rate of 10 to 12 per sec., and that alternate forces having the same periodicity correspond with the oscillations of the wheels, it will be realized how great the forces are that come into play at the critical speed

An instructive discussion followed the presentation of the paper. At the business session, five members were elected as a nominating committee for Section officers for the coming year, and E. V. Rippingille was elected to represent the Section on the Sections Committee of the Society.

HIGH-POWER SMALL CARS VISIONED

President Little Tells Pennsylvania Section Radical Improvements Are Soon Due

Revolutionary development resulting in a small fine car that will be equipped just as luxuriously as the finest car on the American market was predicted by T. J. Little, Jr., in the paper on The High-Performance Small Car which he presented at the meeting of the Pennsylvania Section held at Kugler's Restaurant, Philadelphia, on Nov. 9. He believes that America will not copy the foreign small car but that the influence of racing-engine development will be felt and that the present ideas of engine building will be changed radically on this account. His paper is printed in full in this issue of THE JOURNAL.



T. J. LITTLE, JR.

E. W. Templin, engineer of the motorcoach division of the Six Wheel Co., Philadelphia, presided at the business session, and B. B. Bachman, engineer for the Autocar Co., Ardmore, Pa., was chairman of the meeting. O. N. Thornton, Philadelphia branch manager for the Titeflex Metal Hose Co., was appointed chairman of the Section's Membership Committee. Five members were nominated and elected as a nominating committee for Section officers for the coming year, and C. O. Guernsey was elected to represent the Section on the Sections Committee of the Society. Following the business session, the subject of the most desirable place at which to hold the Semi-Annual Meeting of the Society was discussed, the result being the filing at the general office of the Society of a memorandum to the effect that the Pennsylvania Section requests the Society to consider earnestly

the holding of the Semi-Annual Meeting at some Eastern resort.

MANY PARTICIPATE IN THE DISCUSSION

In opening the discussion of President Little's paper and in specific connection with some of the author's radical predictions for the small car, Chairman Bachman remarked in effect that many things now in successful existence and generally accepted as such originally were frowned upon and criticised as being irrational and uncommercial, but that persistent and thereunto unthought of development eventually had caused them to be created. He thought it likely that the same might be true of the small-car prophecies, and that such development unquestionably will affect all phases of the industry. He believed that economic forces exist, drawn into being by the automobile, which have just begun to come into action, and that their effect is to become evident within the next few years along lines that demand improvement in equipment and in methods. H. L. Brownback outlined his experience with an imported French car of medium size and described in considerable detail various types of the small car existent abroad.

In reply to C. O. Guernsey, chief engineer of the automotive car division of the J. G. Brill Co., Philadelphia, who asked what specifications the future small car is to have, President Little was hesitant in making specific statements but ventured to say that he thought the small car which he has in mind will weigh about 1200 lb., have an engine of say 125 to 150-cu. in. displacement and seat four passengers; and the medium-size car he visions will weigh about 2500 lb., have an engine of 225-cu. in. displacement and carry five passengers. According to his idea, the future seven-passenger car will have an engine of 400-cu. in. displacement and will weigh about 4000 lb.

BETTER PERFORMANCE A GREAT ADVANTAGE

A further question from Mr. Guernsey as to what the selling-points of the small car under discussion would be caused President Little to say that better performance would be the paramount sales argument, since if the new cars did not outperform those now being driven, owners would retain their old cars. He said that body style and good appearance always would constitute an important appeal but the cost of operation is not very important so long as it is not excessively high. He believed that greater economy would be desirable, but stated that greater economy will not sell a car and never has sold it.

Riding-quality will be a very important feature, in President Little's opinion. The small car he refers to must ride easily and he believes it can be made to do so. The wheel-base will be say 100 in. or possibly a few inches greater, according to his belief. He added that he thinks the size and the weight of the large luxurious American car of today will not be decreased very much; in other words, that the large car always will be in demand, his remarks regarding specifications and development applying only to the small and to the medium-size cars.

Chairman Bachman brought out the point that if seat-room for two people is provided in the rear of a car, the car body is slung low, balloon tires are used, and the two passengers on the rear seat ride between the two rear wheels of the car, the matter of width of car tread is rather well-defined. He said also that similar physical and equipment restrictions govern the possible fore-and-aft dimension as well, and indicated that minimum dimensions are already specific to a large degree.

THE MOTOR-VEHICLE AND PROGRESS

Judson F. Lee Discusses Highway Transportation's Social Aspects at Chicago Meeting

Competition, the economic law, has drawn the line clearly between the motor-truck and the railroads and between the motorcoach and the street-car, and the more the fundamental principles are emphasized the

sooner will society realize that the motor-vehicle is a means of reducing the cost of transportation and the cost of living and of raising the standard of living of the American people

remarked Dr. Judson F. Lee, of Lewis Institute, in an address to members of the Chicago Section on Nov. 9.

The meeting was held in the auditorium of the Western Society of Engineers and was presided over by O. W. Young, chairman of the Section, who announced the sudden death of a member of the Section, Claude Robert Alling, who was vice-president of the Underwriters Laboratories. At the chairman's request, D. P. Barnard, 4th, introduced Dr. Lee, the only speaker of the evening, as a student of the economic problems of traffic who has given particular attention to freight distribution in Chicago and the Calumet district.

EACH SYSTEM HAS ITS OWN SPHERE

Dr. Lee's address was a comprehensive survey of the automotive industry and transportation by motor-vehicle in their relation to other forms of transportation and to the economic, educational and social development of the people. He reviewed the changes in transportation methods from the prairie schooner and steamboat to the motor-truck and motorcoach, the statistical status of the motor-vehicle today, highway development at home and abroad, the economic fields of motor-truck and motorcoach operation, and the advantages of the motor-vehicle to the farmer, to industry and to the public, both economically and culturally.

The future market for motor-vehicles is assured and may be dominated by the American builder, he asserted. What relation to the older systems of transportation does this new power bear? he asked. Today it seems clear; each has its own sphere, the one being complementary to the other. The problem is one of coordination, not of competition. The railroad is the wholesale long-distance carrier of the nation; the motor-vehicle can best serve in short hauls, even door-to-door delivery. Whether the motorcoach is now regarded as a competitor of electric and steam-railways is answered by the fact that 134 electric-railways are operating motorcoach lines and 157 steam-railroads are using motor-vehicles as feeders and as extensions from existing rail-lines.

In the discussion, participated in by Chairman Young; D. P. Barnard, 4th; R. E. Wilkin; F. G. Whittington; and Dr. Lee, the question of how the airplane will fit into the transportation scheme was discussed, the relation of the motor-truck to the terminal problem and the extensive use of containers was considered, the elimination or segregation of horse-drawn traffic in congested city streets was touched upon, and the motor-vehicle saturation point received some attention.

RUBBER IN VEHICLE CONSTRUCTION

Indiana Section Holds a Triple-Paper Session on Shock and Noise Insulation

On the evening of Nov. 11, with Chairman Ralph R. Teetor presiding, after a short business session in which a Nominating Committee was appointed and George Briggs was unanimously elected to represent the Indiana Section on the Sections Committee of the Society, a well-attended meeting heard papers from three engineers on different phases of the application of rubber in vehicle construction for shock and noise insulation.

RUBBER AS A MATERIAL FOR MECHANICAL ENGINEERING

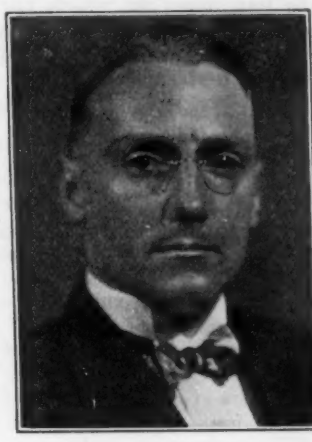
With this as a subject, Dr. W. A. Gibbons, chemical engineer of the United States Rubber Co., dealt with the fundamental mechanical properties of rubber in comparison with those of steel. Among the remarkable characteristics of rubber he pointed out its ability to withstand stretching to 10 or 11 times its length without rupture or appreciable permanent deformation and its tensile strength, figured on the original cross-section, of 5000 lb. per sq. in. or 50,000 lb



Charles Froesch



W. A. Gibbons



C. Saurer



F. E. Moskovics

AUTHORS OF THE THREE PAPERS PRESENTED AT THE NOVEMBER MEETING OF THE INDIANA SECTION AND AN ACTIVE PARTICIPANT IN THE DISCUSSION

per sq. in., calculated on its cross-section at break, thus approaching the strength of steel. Thus, a rubber cube, measuring 1 in. on each edge can be stretched to a total length of 11 in. If the load at this elongation is 4000 lb. the rubber will have absorbed 1600 ft.-lb. of energy. Such a piece of rubber will weigh about 0.04 lb. indicating that 1.00 lb. of rubber, occupying about 25 cu. in., similarly treated will absorb 40,000 ft.-lb. or with this elongation occurring in cycles of 1 min. it will absorb energy equivalent to 1¼ hp. A steel spring capable of doing this would weigh from 50 to 100 lb., depending on the type of steel.

The property of practically perfect restitution of form, with imperfect restitution of energy, possessed by no other material to the same degree, makes rubber valuable as a shock-absorbing material. To secure both the same total and irreversible energy absorption with any other material or materials, we would have to resort to a structure or machine. A dashpot on a steel spring approaches the properties of rubber, but rubber within itself is a combined spring and shock-absorber.

Because of these properties rubber can be used to absorb shocks and vibrations between various parts of chassis and equipment. In many such locations rubber is particularly valuable, since it breaks up vibrations and prevents them from being carried from one part to the other, thus localizing the vibrations and stopping the trouble at the source.

NEW AUTOMOTIVE USES FOR RUBBER

The second paper of the evening was read by C. Saurer, chief engineer for automotive development, of the Mechanical Rubber Co., Cleveland. Rubber has been used for years in automotive construction, such as radiator hose, fan-belts, door bumpers, step mats, anti-rattlers, windshield strips, and tires. In recent years, developments have been made on rubber universal-joints, radius-rod supports, torque joints, balancers, engine supports, and spring mountings.

Mr. Saurer called attention to the great amount of time and experimental work required to develop a suitable compound and manufacturing processes for the production of satisfactory rubber body shims, which are not affected by heat and with long life make a perfect seat between the frame and the body.

While many inferior grades of axle and door-bumpers are found at low prices on the market, rubber bumpers and other moulded parts can be made of such material as to outlast the vehicle. Engine supports and drive-shaft joints necessitate a material capable of absorbing high-frequency vibrations designed especially for such service.

RUBBER AS AN AUTOMOTIVE MATERIAL

Charles Froesch, of the International Motor Co., stated that the most satisfactory grade of rubber used today for chassis mounting and spring shock-insulators is composed

of pure plantation rubber approximately 50 per cent by weight and 90 per cent by volume together with pigments and a filler which is more or less responsible for its ultimate color. It has a specific gravity of 1.7 to 1.8, weighing about 1 oz. per cu. in.

The amount of energy that rubber is capable of storing is from 48 to 50 times as much as that which a piece of machine steel of equal size can store. When subjected to a shock, steel will continue to vibrate for a considerable time as the energy is absorbed very slowly by its intermolecular friction, whereas rubber will absorb it quickly.

The application of rubber shock-insulator mountings to automotive vehicles, particularly motorcoaches, was described in detail and illustrated by lantern slides. These applications covered spring-shackles, torque insulators and mountings for the engine, transmission, radiator, steering post, gasoline tank, motorcoach seat and motor-truck cab.

A lively discussion following the papers further brought out some of the difficulties encountered in the use of rubber, particularly its tendency to deteriorate when exposed to light and heat, and the methods that have been developed to overcome these troubles.

BRAKES HAVE A HEARING

Washington Section Told About Brake Safety-Code, Torque Equalizer and Pivoting



GEORGE L. SMITH

Several new developments relating to brakes were presented by speakers at the brake meeting of the Washington Section on Nov. 5 at the Hotel Hamilton in the national capital following a dinner at which 42 members and guests were present. Conrad Young, vice-chairman of the Section, presided.

Maurice O. Eldridge, director of safety for the District of Columbia, in a short preliminary talk, referred to the new Safety Code for Brakes and read one of a number of letters he had received from residents near boulevard stop-signs who complained of being awakened or being kept

awake by squealing and groaning brakes.

Col. I. C. Moller, assistant director of traffic, told of a new traffic-regulation plan that has been put into effect in the District. Under this plan, the driver of a vehicle whose

brakes, headlights or tires are in bad order or which has other mechanical defects that make it unsafe, is handed a notification by an officer to report within 48 hr. at a specified police station to show that the defect has been remedied.

TORQUE-EQUALIZED BRAKES PREVENT SKIDDING

Lantern slides showing the construction of his torque-equalized brakes were shown by G. L. Smith, who also presented recorder charts made during tests of the device under various road conditions. The purpose of the device is to equalize both the brake and the tire friction. Only by utilizing the tire friction with the road to produce the equalizing action can the force delivered to the road surface on the opposite sides of the vehicle be equalized, he said.

To accomplish this object, the inventor uses bell-cranks and a connecting cross-rod. The cranks are pivoted on the axle, with their vertical arms connected by the cross-rod and their horizontal arms pivoted to the brake-band operating-arms. Thus the brake arms have floating anchorages instead of being anchored to fixed parts of the chassis and are interacting. The brake-bands, therefore, can rotate to a limited extent in opposite directions when unbalanced forces exist; the band that pulls the harder will rotate with its drum and the band pressure on the drum will be reduced. This action automatically reverses the band on the opposite drum, and the backward movement increases the pressure, hence the braking pressure on the two drums is equalized with the tire friction on the road.

MEMBERS LEARN WHY A CAR PIVOTS

Johannes Plum talked on the subject, Why Does a Car Pivot? After analyzing the motion of the car during the pivot and showing how the pivot force was aggravated at that time, he emphasized his conclusion that the two conditions under which a car is brought to a stop, that is, when the weather is conducive to skidding and when it is fair, are so different that a four-wheel-brake system must combine two different methods of appropriate braking in its design to take care of either dry or wet weather driving conditions.

BRAKE CODE AND DYNAMIC BRAKE-TESTER

H. H. Allen, in charge of braking tests for the Bureau of Standards, discussed the Safety Code for Brakes and Brake Tests which has reached the stage of final draft under the sponsorship of the Bureau and the American Automobile Association and was submitted on Nov. 6 to the membership of the Sectional Committee of the American Engineering Standards Committee for balloting. He also described the series of brake tests that provided the basis for formulating the code, and described the Cowdrey dynamic brake-tester. This device is an electric motor-driven transmission-dynamometer for measuring the braking effort at each braked wheel of a motor-vehicle. Its reading is a force reading in terms of pounds of road pull. The claim is made that this device enables one man to adjust even four-wheel brakes in a short time; to distribute the retarding force in any desired ratio on the front and rear wheels; to determine with commercial accuracy in how many feet a vehicle will stop from any selected speed; to detect out-of-round drums, warped or greasy bands and low wheels; and to detect the difference in torsional twist of brake cross-rods.

LOW-COST FLEET-OPERATION

Southern California Section Has Symposium on Latest Practices Presented

Methods used by several leading Los Angeles companies to reduce the cost of fleet operation, maintenance and repair were presented by representatives of these organizations at the meeting of the Southern California Section that was held Nov. 12 at the City Club, Los Angeles. More than 100 reservations were made for the club supper that preceded the

technical session but, on account of rain, only 85 members and guests attended.

Four speakers outlined their experiences in fleet operation, namely, C. G. Bussey, of the Union Oil Co.; R. R. Rutherford, of the Standard Oil Co.; E. F. Rondot, of the Southern California Edison Co.; and E. M. Fitz, of the Shell Oil Co. In addition to the speakers mentioned, about 15 persons took part in the discussion and related their experiences. Owners of large fleets of motor-trucks seem to favor the unit repair system; that is, unit parts are replaced and those removed are then repaired, thus minimizing the out-of-service time for the vehicle.

AIR-CLEANING DEVICES STUDIED

Northern California Section Hears Hoffman's Analysis of Air-Cleaner Tests



A. H. HOFFMAN

Devices for cleaning the air that is taken into internal-combustion engines were analyzed by Prof. A. H. Hoffman at the meeting of the Northern California Section that was held at the Engineers Club in San Francisco on Nov. 18. His paper was entitled Selection of an Air-Cleaner and he also described efficiency tests for radiator fan-type air-cleaners, presenting numerous lantern-slide illustrations. The meeting was preceded by a dinner, and 53 members and guests attended. A committee was appointed to arrange a joint meeting with the Southern California Section

next spring to promote good fellowship and cooperation.

In his paper, Professor Hoffman referred to the 1922 and to the 1924 air-cleaner tests and said that a third series of tests, which covers radiator fan-type cleaners, is now in progress. After discussing the limitations of laboratory tests of air-cleaners, he mentioned that the manufacturer whose product includes internal-combustion engines and who is in search of a satisfactory air-cleaner for use on his product should demand high efficiency and low restriction or vacuum effect and should make sure that the cleaner in question can be installed satisfactorily. Other points that the manufacturer should consider are whether any condition of the installation will interfere with the functioning of the device, whether it will require more attention than the least energetic operator presumably will give it, how fast it will deteriorate if neglected, and whether it will maintain its efficiency indefinitely. The manufacturer also should know whether the vacuum effect of the device is the same after a considerable quantity of dust has been handled; if the device has any moving parts and how long before they will cease to operate because of wear, lack of lubrication or loading with oil and dirt; if small passages are present that will become clogged with dirt, carbon, leaves, or insects; whether it occupies too much space; if the intake can be placed in the position where it will encounter the least dust; and whether it will take care of the auxiliary air-inlets to the carburetor satisfactorily.

SCREEN MATERIAL AND MANNER OF PLACEMENT

The tests were made by the agricultural engineering division of the University of California, and Professor Hoffman made statements of the characteristics of the various types of air-cleaner considered, with comment thereon. He emphasized that the position of the air-intake is of the utmost importance.

(Concluded on p. 546)

AUTOMOTIVE RESEARCH

The Society's activities as well as research matters of general interest are presented in this section

SPRINGS FROM AUTOMOTIVE VIEWPOINT

Report Prepared for Special Research Committee on Mechanical Springs

Upon the invitation of the American Society of Mechanical Engineers, the Society of Automotive Engineers appointed a representative to serve on the Special Research Committee on Mechanical Springs, of which J. Kaye Wood is chairman. Representatives were appointed similarly by the American Society for Steel Treating and the American Society for Testing Materials. The appointees are Dr. M. E. McDonnell, of the American Society for Testing Materials; J. W. Rockefeller, Jr., of the American Society for Steel Treating; and Dr. Benjamin Liebowitz, of the Society of Automotive Engineers.

Each representative was requested to prepare a report on springs, confined to the particular phase of the spring question in which his society is interested. The reports to include the three following divisions:

- (1) Summary of research and standardization accomplished
- (2) Research and standardization in progress and contemplated
- (3) Research work suggested for inclusion in the American Society of Mechanical Engineers' program

These reports are for presentation at the open session of the Special Research Committee on Mechanical Springs to be held during the Annual Meeting of the American Society of Mechanical Engineers, Dec. 6 to 9, 1926.

The report to be submitted by Dr. Liebowitz is printed below in full; preceding it is an abstract including some explanatory remarks and figures that will be helpful to those readers to whom the references given are not available.

The report first discusses the references to standardization and research work accomplished and then gives instances of work in progress. It then takes up in turn the two major problems of motor-vehicle spring-suspensions, (a) the dynamic problem, which deals with the behavior of the car on the road, and (b) the elastic problem, which concerns the design and performance of the spring element itself.

The section on the dynamical problems of spring-suspension enumerates the assumptions that are usually adopted to make a formal mathematical solution obtainable by straightforward dynamical methods. A number of pertinent questions are raised about the validity of these assumptions as applied to certain specific problems that the automotive engineer has to face. It is brought out further that additional restrictions of the scope of the problem are usually adopted to obtain a result that is not too complicated for practical interpretation. However, if the assumptions and restrictions made are kept in view, analysis can yield results of practical value.

EXPERIMENTAL DETERMINATION OF STRESSES IN LEAF-SPRINGS

Elastic problems are then taken up, and first the matter of experimental determination of stresses in leaf-springs is considered. From the common theory of flexure the stress due to the bending of a thin strip is known to be proportional to the thickness of the strip t , its elastic modulus E , and the change of curvature, according to the formula

$$s = \frac{1}{2} E t (1/r_2 - 1/r_1) \quad (1)$$

where r_1 and r_2 are the radii of curvature of the strip before and after bending. Hence, if the thickness of the strip and

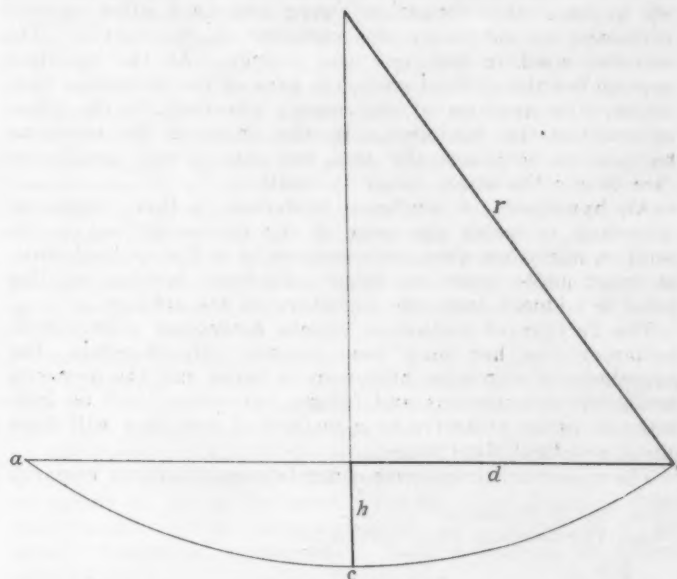


FIG. 1—DIAGRAM ILLUSTRATING THE OPERATION OF INSTRUMENTS OF THE SPHEROMETER TYPE

its modulus are known, the stress can be determined by measuring radii of curvature before and after bending. But such radii are readily found by instruments of the spherometer type employed by opticians for measuring lens radii. The principle of such instruments is illustrated in Fig. 1. If a and b are two points a distance $2d$ apart, and if c is a third point equidistant from a and b and a distance h from the straight line ab , the three points a , b and c lie on a circle whose radius r is given by

$$r = \frac{1}{2} h (d^2 + h^2) \quad (2)$$

or where h is small compared with d , by the approximate formula

$$r = d^2 / 2h \quad (3)$$

as can be shown by elementary geometry.

By laying off equidistant punch-marks on the edges of any plate of a leaf-spring and applying any appropriate form of clamp, the distance h can be determined at any point for any condition of load on the spring by a suitable micrometer arrangement; similar measurements can be made before the plate is assembled in the spring. In this manner, by applying Formula (2) or (3) the radius of curvature of the plate may be obtained at any point in the plate under any condition of load; then, by use of Formula (1), the corresponding stresses can be determined. Measurements of this type have been made by H. S. Rowell, who found rather marked non-uniform distribution of stress in the leaf-springs that he tested.

FATIGUE-TEST RESULTS NOT ADEQUATELY INTERPRETED

The report then takes up the question of fatigue-testing and points out the lack of an adequate interpretation of the practical significance of fatigue results obtained by the methods now in use. Various differences between laboratory fatigue-tests and actual service conditions exist, but the particular difference that is emphasized in this report is the fact that laboratory tests are cyclical or regular, whereas service conditions are more or less acyclical or irregular.

On the other hand, it has long been known that the hysteresis loop of a specimen subjected to cycles of stress

is not a fixed quantity, but depends, among other things, on the number of cycles that the specimen has undergone. Usually, the hysteresis loop tends toward an invariable form when the cycle is repeated many times; the specimen is then said to be in a cyclical state.

A good example of the gradual transition to a cyclical state is given in Fig. 2, which is taken from H. J. Gough's *Fatigue of Metals*. The ordinates represent applied stress, the abscissas are resulting strains. The range of applied stress was kept constant at 4.7 gross tons (10,500 lb.) per sq. in., and the elongations were measured after various reversals, as shown by the numbers on the curves. The material used in this test was copper. As the specimen approached the cyclical state, the area of the hysteresis loop, which is a measure of the energy absorbed by the piece, approached the minimum. In this instance the minimum happens to be practically zero, but that is not usually the case unless the stress range is small.

An hypothesis of minimum hysteresis is then suggested, according to which the area of the hysteresis loop is the relative minimum when the specimen is in the cyclical state, at least under some condition. Evidence bearing on this point is adduced from the literature on the subject.

The fatigue of metals is closely associated with elastic hysteresis, as has long been known. If, therefore, the hypothesis of minimum hysteresis is borne out, the necessity for acyclical hysteresis and fatigue experiment will be indicated in order to arrive at a method of test that will have direct practical significance.

The report concludes with concrete suggestions on research

¹ See S.A.E. HANDBOOK.

² See THE JOURNAL, June, 1926, p. 581.

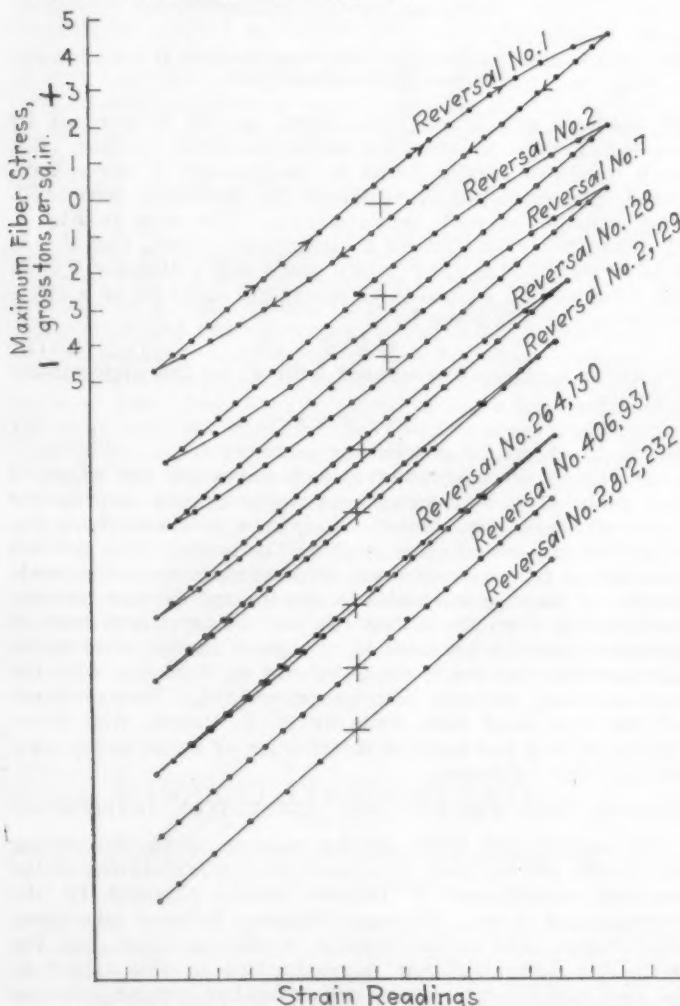


FIG. 2—HYSTERESIS LOOPS UNDER REVERSED BENDING STRESSES
Although These Loops Were Obtained from Tests on Copper for
Stresses That Were Less Than the Limiting Range They Are
Typical Examples

activities for incorporation in the American Society of Mechanical Engineers' program, including researches in the literature, design of acyclic hysteresis apparatus and investigations of stress distribution in leaf-springs.

DR. LIEBOWITZ'S REPORT

The spring suspension of a motor vehicle involves two major problems, (a) dynamic and (b) elastic. The dynamics of suspensions deals with the behavior of the entire car, its various modes and periods of vibration and, in general, with the interactions between vehicle and road. The elastic problem is concerned with the design and performance of the spring element itself.

While relatively little work has been accomplished in the standardization of spring dimensions,¹ the natural processes of commercial evolution have resulted in a more or less complete standardization of form, in a few types, of which the semi-elliptic is most common. This natural standardization, however, does not indicate a dearth of research and invention. In fact, considerable literature both on the dynamical and elastic aspects of the problem is available.

STANDARDIZATION AND RESEARCH ACCOMPLISHED

The standardization of springs by the Society of Automotive Engineers, dating back to about 1911, has related entirely to suspension springs. Investigation following suggestions for standardization of coil springs, such as valve-springs, has indicated that the conditions governing their design and use do not permit of general standardization.

The development of standards for flat or leaf-springs has been restricted almost entirely to dimensional standards providing for interchangeability of mountings and accessory parts, such as spring-eye bushings; center-bolts; rebound clips, spacers and bolts; the widths and thickness of spring leaves; the dimensions of ribs and the standardization of spring-testing blocks. The leaf-spring specifications of the Society are shown on p. H1 to H11a of the S.A.E. HANDBOOK and are the result of periodical checking and revisions to keep the specifications up to date with commercial spring practice.

These standards have been used extensively and have undoubtedly resulted in some reduction of production costs and in permitting quick spring replacements in emergencies.

All of the spring specifications are subject to periodical reviews and will be revised and added to as occasion may require to keep them up to date. The date of adoption and of the latest revisions of the individual spring specifications printed in the S.A.E. HANDBOOK are given in the footnotes in small type following each specification.

The extent of research accomplished is well illustrated by reference to the *Riding-Qualities Bibliography*, compiled by the Research Department of the Society of Automotive Engineers, issued Jan. 20, 1925. This bibliography contains over 500 references, about 150 of which are in the section on Springs, and more than 100 in the section on Instruments. Supplementary lists have been compiled, containing about 60 references to other and later papers on springs.

The intention of this report is not to digest this bibliography but rather to present the main outlines of the spring problem as interpreted by me.

RESEARCH IN PROGRESS

The riding-qualities field has always been a fruitful one for investigation. At the present time, the most extensive research is that undertaken by the Bureau of Public Roads directed toward the measurement of the reactions between the wheel and the road. The Society of Automotive Engineers and the Rubber Association of America are represented on the Joint Committee on Motor-Truck Impacts that acts in an advisory capacity in this work. A progress report on the work done in this investigation during the last few years is given in a paper on General Results of the Co-operative Motor-Truck Impact Tests, by J. H. Buchanan and J. W. Reid.²

The Heat and Power Division of the Bureau of Standards, under the direction of Dr. H. C. Dickinson, has made a

valuable contribution to the instrumentation end of the problem'. Further work on this aspect of the problem, as well as other phases of riding qualities, is in progress there.

Valuable work on the instrumentation question has been done in the engineering laboratories of the Firestone Tire & Rubber Co. under the direction of R. W. Brown. Results accomplished there are described in a paper on Instrumentation and Results of Riding-Qualities Tests, by R. W. Brown'. The work is being continued.

I have also devoted attention to the instrumentation problem', and, with Past-President Manly, am conducting some tests on the accuracy of contact accelerometers'.

These citations are but a few instances of current investigation, and do not aim to be in any way complete.

THE DYNAMICAL PROBLEMS OF SPRING-SUSPENSIONS

With certain assumptions and approximations that (a) the springs and tires obey Hooke's law, (b) the friction is viscous, (c) the body is rigid, and (d) roll and yaw have negligible coupling with pitching and bouncing, the vertical motions of a vehicle body and running-gear can be worked out by straightforward dynamical methods. Both the free and the forced motions may be obtained, by assuming appropriate road-conditions.

But, granting that the solution has been obtained, a number of questions may be raised legitimately:

- (1) Has anything of importance been thrown out of a calculation by the assumptions concerning yaw and roll?

This question has a possible bearing on steering in general and shimmy in particular.

- (2) Can a fair estimate of the accelerations of the body be obtained if the body is considered rigid?

The rigidity of the frame, body and load has an important influence; for example, a motor-truck fully laden with concrete blocks may ride more comfortably than a passenger-car. In general, the local accelerations of a vehicle body resulting from a road impact are considerably greater than would be indicated by the inertia of the body and the instantaneous maximum spring deflection. This is accounted for, at least in part, by the fact that the vehicle body and its load do not constitute a rigid mass.

- (3) How important is body flexibility in damping?

The amount of friction necessary in the suspension to secure adequate damping is known to be less than ordinary theoretical calculations indicate. Here again the flexibility, and capacity for energy dissipation, of the vehicle frame, body and load plays an important role. It is noteworthy that when side-rails became deeper, the need for shock-absorbers became more apparent.

- (4) Is it sufficiently accurate for all practical purposes to regard the friction as viscous, proportional to velocity?

If the friction of the suspension is assumed to be viscous and theoretically sufficient for aperiodicity, it is found that the viscous forces impressed on the body under ordinary road conditions may exceed the elastic forces considerably. In practice, however, the friction is less than that theoretically required (see 3), and is not viscous, unless certain types of shock-absorber are used. And, in the latter event, the friction is usually unilateral and acts downward only on the body. The circumstance is mentioned merely to point out the necessity of properly interpreting analytical results based on the viscous friction hypothesis.

- (5) Can the analysis be simplified to the point of usefulness without sacrificing accuracy to the point of uselessness?

- (6) What actual practical design criteria can be obtained from the analysis?

The last two questions bring to a focus the real difficulties of the dynamical problem and will be discussed further.

The complete straightforward solution outlined above is complicated in detail and yields results too cumbersome for practical calculation or interpretation. The usual method has been, therefore, to simplify the problem by limiting the scope of the analysis. Useful results have been obtained in this way. For example, a good concept of the wheel and body trajectories' following a shock may be obtained by considering one wheel and a suspended mass centered over it; the effects of speed, unsprung weight and the like may be studied in this manner. Again, the free vibrations of a vehicle may be worked out by the methods of J. J. Guest', described in an article entitled Main Free Vibrations of an Autocar. He, by the use of reciprocal theorems, has gone far toward reducing the results to simple, usable form. Such partial analyses may often have practical value, but care must be exercised in interpreting them broadly.

Given the nodes of free vibration, the amplitudes and frequencies, question (6) remains, What design criteria does this knowledge afford? Professor Guest' offers the suggestion that the doubly conjugate points, where the free vibrations are simple harmonic, are the most comfortable and should therefore dictate the location of the seats. Investigation of a physiological and psychological nature may be necessary to decide the point. On the other hand, further analysis may reveal other purely physical properties of the doubly conjugate points which have a bearing on riding qualities.

ELASTIC PROBLEMS OF SPRINGS

The most important applications of the dynamical problems outlined lie in the automotive field, in relation to the riding qualities question. The elastic problems, however, are of less restricted application and are, therefore, of more immediate interest to the special Research Committee on Mechanical Springs.

Of first importance to the engineer is the fiber stress imposed on a spring under given load conditions. Such stresses have been determined solely by calculation, using the common theory of flexure and appropriate assumptions. To determine such stresses experimentally, at arbitrary points in any plate of a leaf-spring, is entirely feasible, however, as was shown in an excellent paper entitled Experiments on Laminated Springs, by H. S. Rowell'. The instruments used are based on the simple geometric principles of the spherometer or cylindrometer.

Rowell found the stress distribution in leaf-springs anything but uniform. Such investigations may, therefore, yield important, practical results.

While many important data have been and are being gathered in fatigue testing laboratories, we have not as yet arrived at an adequate interpretation of the practical significance of the results. This is an outstanding problem in spring design. One of the objects of this report is to adduce evidence indicating that elastic hysteresis under acyclical conditions may have an important bearing on this problem and to offer concrete suggestions for research along such lines. Laboratory fatigue-tests and actual service-conditions generally differ in two important respects: (a) purity of specimen and (b) purity of test conditions. The latter includes several variables, all of which may be important, but special attention is here directed to one particular variable, the cyclic nature of laboratory tests compared with the acyclic or irregular stresses encountered in service.

The term cyclical state appears often in the literature. Mayo D. Hersey, in a paper On the Theory of Irreversible Time Effects,¹⁰ defines the cyclic state as one "in which the hysteresis loop has an invariable form." There is reason to believe that the cyclic state is also one in which the hysteresis is the relative minimum, at least under some conditions. This

¹ See THE JOURNAL, March, 1926, p. 248.

² See THE JOURNAL, June, 1926, p. 593.

³ See THE JOURNAL, March, 1926, p. 248.

⁴ See THE JOURNAL, November, 1926, p. 433.

⁵ See S.A.E. BULLETIN, May, 1916, p. 158.

⁶ See Proceedings of the Institution of Automobile Engineers, vol. 20, p. 505.

⁷ See Proceedings of the Institution of Automobile Engineers, vol. 20, p. 589.

⁸ See Journal of the Washington Academy of Sciences, vol. 11, p. 149.

concept will be referred to as the hypothesis of minimum hysteresis.

Ewing's work on magnetic hysteresis is of interest in this connection. Also Bairstow's results¹¹ indicate a definite trend in this direction under some test conditions. Reference may also be made to magnetostriction phenomena, studied by the Bureau of Standards.¹² H. F. Moore¹³ reported cases in which steel after a few thousand cycles of stress became appreciably hot, and then after some millions of cycles of stress with no interval of rest became cool again! This result fits in with the minimum hysteresis hypothesis.

Emphasis should be laid on the point that this hypothesis does not imply an absolutely unchanging hysteresis; from the time of Kelvin's experiments¹⁴ the tendency of internal metallic friction to increase under repeated stress has been known. The present hypothesis assumes a relative, not the absolute, minimum.

If this view is correct, fatigue results will depend more or less on the cyclic or acyclic conditions of test. So far as I know only two instances have been reported in which the cycle was varied. In one case¹⁵ the speed was varied, with highly interesting results. In the other case, which is given in a report of the British Association, the exact

¹¹ See *Fatigue of Metals*, by H. J. Gough, p. 122.

¹² See Bureau of Standards Scientific Paper No. 272, p. 191.

¹³ See University of Illinois Engineering Experiment Station Bulletin No. 142.

¹⁴ See *Encyclopaedia Britannica*, ninth edition, article on Elasticity.

¹⁵ See *Proceedings of the Royal Society of London*, vol. 92A, p. 373.

reference to which is not available at this writing, the stress range was changed, with apparently marked influence on the fatigue life.

It is submitted, therefore, that in limiting laboratory fatigue-tests to the simple case of fixed cycle and speed, we may be permitting important phenomena to escape our notice; and, further, that systematic investigation of hysteresis and fatigue phenomena under acyclical conditions may yield results of more direct practical significance than have so far been obtained from the conventional methods of test.

SUGGESTED RESEARCH WORK

I suggest, first, that a more thorough search of the literature be made for evidence bearing on the changes in hysteresis which follow changes in the fatigue cycle; that the matter of the cyclical state and its influence on fatigue tests be thoroughly investigated in the literature. Moreover, the design of apparatus should be undertaken with the object of experimentally investigating elastic hysteresis under acyclical conditions, and cyclical also, of course, with a view to determining a subsequent program for fatigue testing under acyclical conditions. I believe that studies in hysteresis will afford a basis on which to devise apparatus and methods for acyclical fatigue testing.

Experimental studies in stress distribution in leaf-springs should also be undertaken, according to the methods of Rowell or by equivalent methods. Such investigations may lead to very useful results in spring design and manufacture, including the possibility of an appreciable saving of material.

MEETINGS OF THE SOCIETY

(Concluded from p. 542)

The additional tests have indicated that a more satisfactory screen for use under an engine hood can be made of strips of thin white felt $\frac{1}{4}$ in. wide and slightly oiled, placed on frames made of $\frac{1}{4}$ -in. iron rod, the strips being woven into a network, the meshes of which are square and spaced on $1\frac{1}{4}$ -in. centers. White mosquito netting used for the same purpose was unsatisfactory, being too coarse of mesh and too fine of thread. Cheesecloth, also, was unsatisfactory, being of too small mesh. White hospital gauze gives fairly satisfactory results but not so satisfactory as the screen made of strips of white felt. For mapping the dust outside the hood, for example, around a tractor, white muslin lightly oiled has been found satisfactory. White felt, lightly oiled, undoubtedly would be highly satisfactory and perhaps would be better than muslin.

Professor Hoffman said also that in studying dust distribution under the hood of an engine or wherever strong air-blasts are met, the fact that any obstruction in the path of the dusty air will act as an air-cleaner for the space in the lee of the obstruction should be borne in mind. Hence, if no air-cleaner is to be installed, the quantity of dust drawn in may conceivably be reduced considerably by the simple expedient of turning the carbureter inlet backward, if it was turned forward in the original installation. A still more marked reduction might be secured by using a tube extending from the cleanest place under the hood to the air-inlet of the carbureter.

A lively discussion followed the presentation of the paper, and many remarked that they had not previously realized the importance of air-cleaners.

CARBURETION AND DISTRIBUTION

Hal H. Timian Discusses Their Relation to Engine Performance at Buffalo

How carburetion and intake-manifold design affect the performance of engines was the subject discussed at the Nov. 9 meeting of the Buffalo Section, in a paper presented by Hal H. Timian, of the Stromberg Motor Devices Co. No synopsis of this paper and the discussion on it can be given herein, as the paper and stenographic report of the discussion had not been received up to the time of closing the Section Meetings reports for the December issue of *THE JOURNAL*.

Chairman H. T. Youngren, of the Buffalo Section, reporting on the Section business disposed of at the meeting, stated that P. B. Jackson, assistant engineer of the Pierce-Arrow Motor Car Co., was elected to represent the Section on the Sections Committee of the Society for the coming year, and that a nominating committee for the nomination of Section officers for next year was elected as follows: Gustaf Carvelli, Arthur Nutt, John C. Talcott, J. W. White, and H. T. Youngren.



STANDARDIZATION ACTIVITIES

The work of the Divisions and Subdivisions of the S.A.E. Standards Committee and other standards activities are reviewed herein

BRAKE AREAS AND POWER BRAKES

Motorcoach Division To Investigate Power-Brake Auxiliary Attachments

A great increase in intercity and interstate transportation by motorcoach has brought many problems, among the foremost of which have been the adequacy of brakes and the development of power brakes. The Motorcoach Division, at a meeting in Boston on Nov. 17, considered both of these important points in an endeavor to determine a basis for standards of brake area and power-brake auxiliary equipment mountings.

Protracted discussion of the best methods of determining required braking area and attendant factors, such as unit pressures, heat dissipation, and types of lining or metallic brakeshoe, indicated that too many variables are involved to arrive at immediate conclusions. But this topic was scheduled for future consideration. The increasing use of power brakes has raised the point of the lack of standard mountings and methods of driving necessary auxiliaries, which is beginning seriously to handicap the engine builder and will result in more or less increased cost to the user and, in some degree, in hindering the adoption of power brakes in fields where they should logically find their greatest use.

While some engine builders have already provided air-compressor mountings and drives that are, more or less, standard on their own models, little organized attempt has been made to provide a standard mounting that will make possible the installation of power brakes on all engines without trouble and undue cost; likewise, no provision has been made for the necessary booster-brake attachment on intake-manifolds.

Inasmuch as the term "airbrakes" has been considered limiting, the name of the Subdivision on Airbrakes that has been organized under the S.A.E. Motorcoach Division has been changed to the Subdivision on Power Brakes, and the Subdivision will undertake as its first work the standardization of air-compressor mountings and the necessary corrections in intake-manifolds to permit the application of booster-brake attachments.

DISTRIBUTOR-ROTOR ELECTRODE

New Terms To Be Included in Electrical Equipment Nomenclature

The Society recently received an inquiry as to the proper name for that part of a timer-distributor rotor from which the high-tension spark jumps to the cap segments in the type of timer-distributor rotor that has a small electrode rather than a carbon brush. The term suggested for adoption was Distributor-Rotor Electrode and, as the members of the Division considered this as descriptive as any that could be used, the Division has recommended that it be added to the S.A.E. Nomenclature, immediately following the term Distributor-Rotor Brush on p. K7 of the S.A.E. HANDBOOK.

The Subdivision on Ground-Return Wiring System has as a result of its work proposed that the term Load-Limit Controller be included in the S.A.E. Nomenclature to designate the protective element that is frequently used in the generator circuit to prevent overload on a voltage-regulated shunt-wound generator. The Division also recommends that

this term be inserted in the standard nomenclature, immediately following the term Current-Voltage Regulator on p. K9 of the S.A.E. HANDBOOK.

CORRECT ANGLE OF LEATHER V-BELTS

The attention of the members of the Subdivision on Fan-Belts and Pulleys has recently been called to the fact that the present S.A.E. Recommended Practice covering the angle of V-belts is not satisfactory for leather belting. The present specification reads as follows:

The included angle of the sides of rubber V-belts shall be 32 deg. when apparatus other than the fan is driven by the same belt and 42 deg. when the fan alone is driven, so as to allow for the bulging of the inside of the belt when laid around the pulleys.

The suggestion is that the following sentence, referring specifically to leather belts, be included in this specification:

The included angle of the sides of leather V-belts shall be the same as the angle of the pulley groove; that is, 28 deg. when apparatus other than the fan is driven by the same belt, and 38 deg. when the fan alone is driven.

This suggestion has been made as many manufacturers and engineers have specified leather belts in accordance with the requirements for rubber belts and have consequently failed to obtain the best results.

GROUND-RETURN WIRING SYSTEM

Report on Revised Standard Approved for Lighting and Starting Circuits

The Electrical Equipment Division, at its meeting in Detroit on Nov. 9, reviewed the report of the Subdivision that was prepared as a revision of the present S. A. E. Standard, p. B28 of the S.A.E. HANDBOOK. This work has been in progress for some time and the latest revision is the result of general circulating of the Subdivision's preliminary report. The report as approved by the Electrical Equipment Division follows:

The systems of installation commonly known as two-wire or single-wire, shall be termed respectively insulated return and ground-return systems.

Installations in which the chassis frame is used as part of the return circuit shall be considered as ground-return systems.

Insulated Cable.—All insulated cable shall conform to the S.A.E. Standard. S.A.E. Standard colors shall be used as a means of identification. Copper terminals on other than starting-motor cables shall be clamped to the insulation and soldered to the conductors. S.A.E. Standard terminals or lugs shall be used on starting-motor cables. Conductor cross-sections shall be not less than the equivalent of No. 16. B. & S. gage and the potential loss at normal load shall not exceed 3 per cent.

Conduit.—Insulated cable shall be protected by metal armor, or unpacked metallic or non-metallic conduit except where otherwise protected or not in contact with metal surfaces. Metallic conduit shall be provided with ferrules having rounded edges at open ends and where it enters junction-boxes. Metallic conduit covering insulated cable leading to a connector shall be soldered

inside of a sleeve member of the connector. Non-metallic conduit shall be provided with metal clamps at the entrance to junction-boxes or at connectors. Wires unprotected with conduit shall be cleated at intervals not exceeding 28 in. Wires protected with conduit shall be cleated at intervals of not more than 36 in. with metal clips secured by bolts or wood screws. Staples shall not be used. No wire shall be nearer to the exhaust-pipe than 2 in. A minimum clearance of 1 in. shall be maintained between any running line of conduit or wires and the carbureter, gasoline pipe, gasoline tank, or any moving part. All holes in metal members through which cables not in conduit pass, shall have edges rolled or shall be provided with rubber bushings.

Grounding.—Wherever a conductor is connected to ground it shall be installed so as to be accessible for repair. Ground-return connections shall be made to the chassis frame or to a substantial part which is firmly attached to the frame at two or more places. Ground connections shall be made to the frame by terminals soldered to the conductors. The surfaces on which the terminals make contact shall be clean and free from oxide or paint. The terminals shall be fastened to the frame by screws or bolts. The storage-battery shall be grounded on the positive side by a conductor securely bolted to the frame, not to an attached member. The contact surface on frames should be tinned.

Battery Installation.—The battery shall be installed so that an overflow of electrolyte will not cause appreciable leakage of current. The storage-battery compartment, or metal parts near the storage-battery, shall be painted with an acid resisting paint and shall be provided with openings of a size to provide ample ventilation and drainage. At the point where the live line passes through a metal compartment the cable shall be protected against grounding by an acid and waterproof insulating bushing. Where a battery and a gasoline tank are both placed under the driver's seat they shall be partitioned from each other. Each compartment shall be provided with an independent cover, ventilation and drainage.

Overload Protective Devices.—The current to all low-tension circuits, except starting-motor and ignition circuits, shall pass through protective devices connected to the battery-feed side of switches. The circuits shall be arranged so that the opening of a protective device will not extinguish all the lights. The inspection-lamp cord plug-socket shall be connected to an unprotected live circuit. A permanently connected inspection lamp or accessory cord shall be protected independently of the lighting.

Protection Against Accidental Short-Circuits.—Connecting posts on fuse and junction-blocks shall be enclosed as a protection against accidental short-circuits.

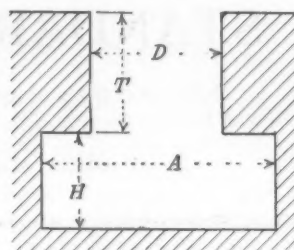


TABLE 1—PROPOSED DIMENSIONS FOR T-SLOTS

Diameter of T-Bolt ¹	Width of Throat ^{1,2} D	Depth of Throat T		Head Space Dimensions and Tolerances					
		Maximum	Minimum	Width A			Depth H		
				Maximum Basic	Tolerance Minus	Minimum	Maximum Basic	Tolerance Minus	Minimum
1/4	9/32	3/8	1/4	9/16	0.003	1/8	15/64	0.031	13/64
5/16	11/32	7/16	5/16	21/32	0.003	15/32	15/64	0.031	13/64
3/8	13/32	15/16	3/4	25/32	0.003	1 1/8	15/64	0.031	13/64
1/2	1 1/16	1 1/8	1 1/4	3 1/8	0.003	1 5/8	25/64	0.031	23/64
5/8	1 1/8	1 3/8	1 1/2	3 7/8	0.003	1 7/8	25/64	0.031	23/64
3/4	1 3/8	1 5/8	1 3/4	4 1/8	0.004	2 1/8	25/64	0.031	19/32
7/8	1 5/8	1 7/8	1 7/8	4 7/8	0.004	2 1/2	25/64	0.047	23/32
1	1 7/8	2	2	5 1/8	0.004	2 3/4	1 1/8	0.063	1 1/2
1 1/4	2 1/8	2 3/8	2 1/2	6 1/8	0.004	3 1/8	1 1/8	0.063	1 1/2

All dimensions in inches.

¹In addition to the "width of throat" given above, a secondary standard is recognized, having the "width of throat" the same as the nominal diameter of the T-bolt. This is to provide for the use during the transition period of this standard on many machine-tools where it is already established.

"Width of tongue" to be used with the above T-slots will be found in Table 5.

²A tolerance of minus 0.001 is allowed for "width of throat" when tongues or other parts must fit.

Robert T. Hazelton
E. G. Herndon
LeRoy F. Maurer

Cincinnati
Navy Department
Studebaker Corporation of
America
Pratt & Whitney Co.

Frank O. Hoagland

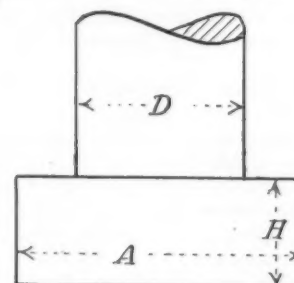


TABLE 2—PROPOSED DIMENSIONS FOR T-BOLTS

Diameter of T-Bolt ^{1, 2}	Threads per In. ¹	Bolt Head Dimensions and Tolerances						
		Width Across Flats A			Width Across Corners	Height H		
		Maximum Basic	Tolerance Minus	Minimum		Maximum Basic	Tolerance Minus	Minimum
$\frac{1}{4}$	20	$\frac{15}{32}$	0.031	$\frac{7}{16}$	0.663	$\frac{5}{32}$	0.016	$\frac{9}{64}$
$\frac{5}{16}$	18	$\frac{9}{16}$	0.031	$\frac{11}{16}$	0.796	$\frac{5}{16}$	0.016	$\frac{11}{64}$
$\frac{3}{8}$	16	$1\frac{1}{16}$	0.031	$1\frac{1}{8}$	0.972	$\frac{5}{8}$	0.016	$1\frac{15}{64}$
$\frac{1}{2}$	13	$1\frac{1}{8}$	0.031	$1\frac{3}{4}$	1.238	$\frac{5}{8}$	0.016	$1\frac{19}{64}$
$\frac{5}{8}$	11	$1\frac{3}{8}$	0.031	$1\frac{5}{8}$	1.591	$1\frac{1}{8}$	0.016	$2\frac{23}{64}$
$\frac{3}{4}$	10	$1\frac{7}{8}$	0.031	$2\frac{1}{8}$	1.856	$1\frac{3}{8}$	0.031	$2\frac{1}{2}$
1	8	$2\frac{1}{8}$	0.031	$2\frac{3}{4}$	2.387	$1\frac{7}{8}$	0.031	$3\frac{21}{64}$
$1\frac{1}{4}$	7	$2\frac{3}{4}$	0.031	$3\frac{1}{4}$	2.917	$2\frac{1}{8}$	0.031	$3\frac{25}{64}$
$1\frac{1}{2}$	6	$3\frac{1}{4}$	0.031	$4\frac{1}{4}$	3.536	$2\frac{3}{4}$	0.031	$4\frac{15}{64}$

All dimensions in inches.

¹Tolerances for diameters of bolts or studs and for threads are in accordance with the American Standard Screw Threads, Coarse Thread series, Medium Fit (Class 3). If a free or close fit thread is desired the tolerances given in the American Standard Screw Threads for either of these classes of fit shall be followed.

²T-slots to be used with these bolts will be found in Table 1.

T-SLOTS, BOLTS, NUTS AND CUTTERS

Production Division Approves Sectional Committee Report on These Subjects

This report, which is the first one issued by the Sectional Committee on Small Tools and Machine-Tool Elements, was formulated by the following Subcommittee:

Erik Oberg, <i>Chairman</i>	<i>Machinery</i>
Herman Casler, <i>Secretary</i>	Canastota, N. Y.
Joseph B. Armitage	Kearney & Trecker Corporation
Joseph W. C. Bullard	Bullard Machine Tool Co.
Luther D. Burlingame	Brown & Sharpe Mfg. Co.
Edward P. Burrell	Warner & Swasey
Harry Cadwallader, Jr.	Standard Shop Equipment Co.

STANDARDIZATION ACTIVITIES

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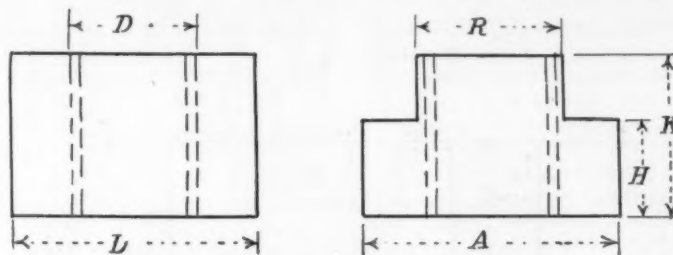


TABLE 3—PROPOSED DIMENSIONS FOR T-NUTS

Tap for Stud ¹ D		Width of Throat T-Slot	Width of Tongue R			Width of Nut ² A			Height of Nut ² H			Total Thickness, Including Tongue K	Length of Nut ² L
Diameter	Threads per In.		Maximum Basic	Tolerance Minus	Minimum	Maximum Basic	Tolerance Minus	Minimum	Maximum Basic	Tolerance Minus	Minimum		
1/4	20	11/32	0.330	0.010	0.320	9/16	0.031	17/32	3/16	0.016	11/64	9/32	9/16
5/16	18	11/16	0.418	0.010	0.408	11/16	0.031	21/32	1/4	0.016	15/64	3/8	11/16
3/8	16	9/16	0.543	0.010	0.533	7/8	0.031	27/32	5/16	0.016	19/64	17/32	7/8
1/2	13	11/16	0.668	0.010	0.658	1 1/8	0.031	1 3/32	13/32	0.016	25/64	5/8	1 1/8
5/8	11	13/16	0.783	0.010	0.773	1 5/16	0.031	1 9/32	17/32	0.031	1/2	25/32	1 5/16
3/4	10	1 1/16	1.033	0.015	1.018	1 11/16	0.031	1 21/32	1 1/16	0.031	21/32	1	1 11/16
1	8	1 5/16	1.273	0.015	1.258	2 1/16	0.031	2 1/32	1 15/16	0.031	23/32	1 5/16	2 1/16
1 1/4	7	1 7/8	1.523	0.015	1.508	2 1/2	0.031	2 15/32	1 3/4	0.031	1 1/2	1 3/8	2 1/2

All dimensions in inches.

¹ When T-nuts are used, stud D is made smaller than the corresponding T-bolt, to assure the full strength of T-nut.² T-slot dimensions to fit the above T-nuts will be found in Table 1.³ There are no tolerances given for the "total thickness" or "length of nut" as they need not be held to close limits.George Langen
Edson R. NorrisCincinnati Planer Co.
Westinghouse Electric &
Mfg. Co.
Columbia University

Charles W. Thomas

This Subcommittee was organized in 1924 and held a series of meetings, at which data collected as the basis for the standard were drafted into a preliminary report. This was submitted to the Production Division of the S.A.E. Standards Committee for criticism and subsequently revised and approved by the Sectional Committee and submitted to the American Society of Mechanical Engineers, the National Machine Tool Builders' Association and this Society for approval as sponsors.

When the report has been approved and adopted it will be of much value to machine-tool builders and users in unifying the individual and varying standards that have come into use by machine-tool builders, some of which have been based on the strength of ordinary gray iron used in the table castings or other places where T-slots are located, and of comparatively low-grade steel for the bolts or studs. Other T-slots have been based on harder table material and on bolts and studs made from stronger stock. In preparing the report, consideration has been given to the factors that should control standardization, such as providing sufficient clearance for oil and chips and for free sliding of the T-bolts in their slots. The Sectional Committee feels that the recommendation agrees closely with good practice in machine-tool construction, although the throat of the recommended T-slots is somewhat greater than the nominal diameter of the bolts, as it is believed that this practice should eventually become generally standard. A temporary alternative standard having a throat width equal to the nominal diameter of the bolt is provided, however, for use during the transition period of the standard.

The Production Division of the Standards Committee has approved the report for adoption as tentative American Standard by a majority ballot with no dissenting votes and similarly for adoption by the Society as S.A.E. Recommended Practice. If so approved by the Society at the Annual Meeting in January, the report will be the first one relating to production machinery used by the automotive

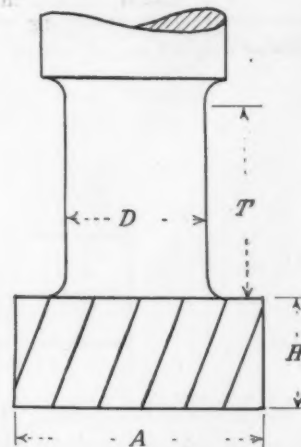


TABLE 4—PROPOSED DIMENSIONS FOR T-SLOT CUTTERS

Width of Throat ^{1,2}		Thickness of Cutter H		Diameter of Cutters A		Diameter of Neck ² D	Length of Neck T
Standard	Nominal Bolt Size	Maximum	Minimum Worn	Maximum	Minimum Worn		
9/32	1/8	15/64	13/64	9/16	1/2	17/64	3/4
11/32	5/16	17/64	15/64	21/32	19/32	21/64	7/8
1/16	3/8	21/64	19/64	23/32	21/32	19/64	1 1/8
9/16	1/2	25/64	23/64	31/32	29/32	17/32	1 1/16
11/16	5/8	29/64	27/64	1 1/4	1 1/8	21/32	1 1/8
13/16	3/4	33/64	31/64	1 5/8	1 1/2	25/32	1 1/4
1 1/16	1	37/64	35/64	1 7/8	1 3/4	1 1/32	1 1/2
1 1/8	1 1/4	41/64	39/64	2 1/8	2 1/4	1 1/8	1 3/4
1 1/4	1 1/2	45/64	43/64	2 3/4	2 1/2	1 1/4	2

All dimensions in inches.

¹ The "width of throat" given in the above table corresponds to that given in Table 1 on T-slots.² In addition to the "width of throat" given above, a secondary standard is recognized, having the "width of throat" the same as the nominal diameter of the T-bolt. This is to provide for the use, during the transition period, of this standard on many machine tools where it is already established. If the narrower throat is used, the diameter of neck D should be reduced accordingly.

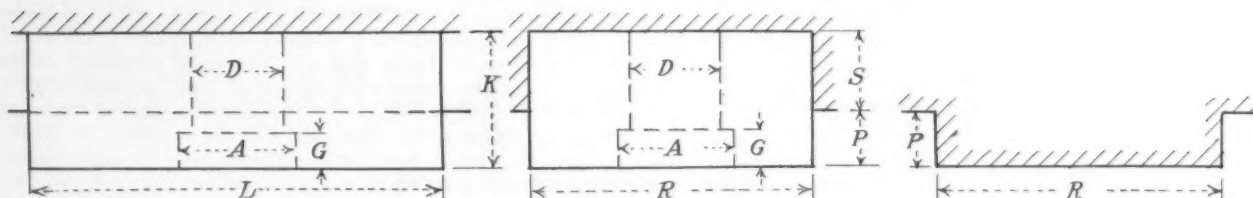


TABLE 5—INSERTED OR SOLID PLAIN TONGUES AND TONGUE SEATS FOR SINGLE WIDTH T-SLOTS

Diameter of T-Bolt ¹	Tongue Dimensions			Depth of Seat S	Total Thickness K	Screw Dimensions				
	Width ^{1,2} R	Length ³ L	Projection P			Diameter of Screw D	Number of Screw	Threads per In.	Diameter of Head A	Thickness of Head G
1/4	9/32	3/8	3/32	1/8	7/32	0.125	5	40	0.196	0.081
5/16	11/32	15/32	1/8	5/32	9/32	0.164	8	32	0.260	0.107
3/8	7/16	9/16	1/8	3/16	5/16	0.190	10	24	0.303	0.124
1/2	9/16	3/4	1/8	7/32	11/32	1/4	.....	20	0.375	0.130
5/8	11/16	13/16	1/8	1/4	3/8	1/4	.....	20	0.375	0.130
3/4	13/16	1 1/8	5/32	9/32	7/16	5/16	.....	18	0.438	0.150
1	1 1/16	1 1/2	7/32	11/32	9/16	3/8	.....	16	0.500	0.170
1 1/4	1 5/16	1 7/8	1/4	3/8	5/8	3/8	.....	16	0.500	0.170
1 1/2	1 9/16	2 1/4	5/16	7/16	3/4	1/2	.....	13	0.625	0.210

All dimensions in inches.

¹In addition to the "width of tongue" given in the above table, a secondary standard is recommended having a width the same as the "nominal diameter of bolt." This is to provide for the use, during the transition period, of this standard on many machine-tools where it is already established.

²The "width of tongue" in the above table corresponds to the "width of throat" for T-slots in Table 1.

³The "length of tongue" can be varied to suit conditions.

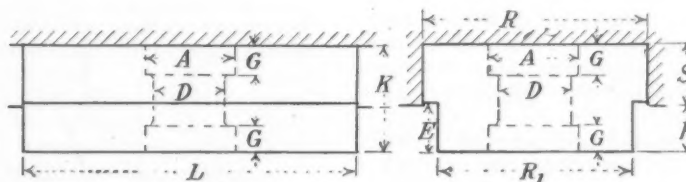


TABLE 6—PROPOSED DIMENSIONS FOR REVERSIBLE TONGUES AND TONGUE SEATS FOR SLOTS FOR TWO SIZES OF T-BOLTS

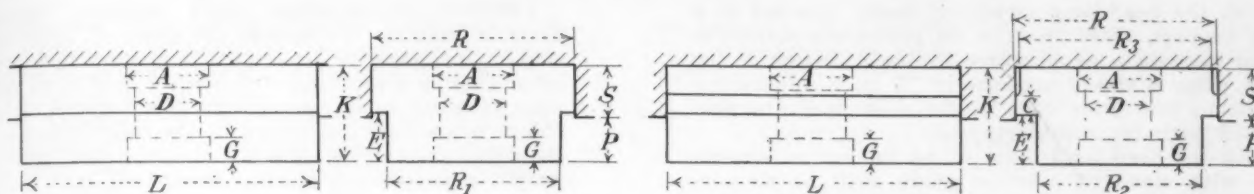
Diameter of T-Bolt		Tongue Dimensions				Depth of Seat	Total Thickness Including Tongue	Height of Shoulder	Screw Dimensions				
Small	Large	Width ^{1,2}		Length ³	Projection				Diameter of Screw	Number of Screw	Threads per In.	Diameter of Head	Thickness of Head
		R ₁	R											L	P	S	K	E	D	A	G
1/4	5/16	9/32	11/32	15/32	1/8	5/32	9/32	1/8	0.164	8	32	0.260	0.107
5/16	3/8	11/32	7/16	9/16	1/8	3/16	5/16	5/64	0.190	10	24	0.303	0.124
3/8	1/2	7/16	9/16	3/4	1/8	7/32	11/32	5/32	0.250	.....	20	0.375	0.130
1/2	5/8	9/16	11/16	15/16	1/8	1/4	3/8	5/32	1/4	.....	20	0.375	0.130
5/8	3/4	11/16	13/16	1 1/16	5/32	5/32	7/16	3/16	5/16	.....	18	0.438	0.150
3/4	1	13/16	1 1/16	1 1/2	7/32	11/32	9/16	1/4	5/8	.....	16	0.500	0.170
1	1 1/4	1 1/16	1 5/16	1 7/8	1/4	3/8	5/8	5/32	3/8	.....	16	0.500	0.170
1 1/4	1 1/2	1 9/16	1 11/16	2 1/4	5/16	7/16	3/4	11/32	1/2	.....	13	0.625	0.210

All dimensions in inches.

¹In addition to the "width of tongue" given in the above table, a secondary standard is recommended having a width the same as the "nominal diameter of bolt." This is to provide for the use, during the transition period, of this standard on many machine-tools where it is already established.

²The "width of tongue" in the above table corresponds to the "width of throat" for T-slots in Table 1.

³The "length of tongue" can be varied to suit conditions.

TABLE 7—PROPOSED DIMENSIONS FOR REVERSIBLE TONGUES AND TONGUE SEATS FOR T-SLOTS¹ OF TWO WIDTHS USING THE SAME SIZE T-BOLT

Diameter of T-Bolt	Tongue Dimensions				Depth of Seat <i>S</i>	Total Thick- ness, Includ- ing Tongue <i>K</i>	Height of Shoulder <i>E</i>	Screw Dimensions				
	Width ²		Length ³ <i>L</i>	Pro- jection <i>P</i>				Diam- eter of Screw <i>D</i>	Number of Screw	Threads per In.	Diam- eter of Head <i>A</i>	Thick- ness of Head <i>G</i>
	<i>R</i> ₁	<i>R</i>										
$\frac{1}{4}$	$\frac{1}{4}$	$\frac{9}{32}$	$\frac{3}{8}$	$\frac{3}{32}$	$\frac{1}{8}$	$\frac{7}{32}$	$\frac{3}{32}$	0.125	5	40	0.196	0.081
$\frac{5}{16}$	$\frac{5}{16}$	$\frac{11}{32}$	$\frac{15}{32}$	$\frac{1}{8}$	$\frac{5}{32}$	$\frac{9}{32}$	$\frac{1}{8}$	0.164	8	32	0.260	0.107
$\frac{3}{8}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{9}{16}$	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{5}{16}$	$\frac{9}{64}$	0.190	10	24	0.303	0.124
$\frac{1}{2}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{3}{4}$	$\frac{1}{8}$	$\frac{7}{32}$	$\frac{11}{32}$	$\frac{5}{32}$	$\frac{1}{4}$	....	20	0.375	0.130
$\frac{5}{8}$	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{15}{16}$	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{5}{32}$	$\frac{1}{4}$	....	20	0.375	0.130
$\frac{3}{4}$	$\frac{3}{4}$	$\frac{13}{16}$	$1\frac{1}{8}$	$\frac{5}{32}$	$\frac{9}{32}$	$\frac{7}{16}$	$\frac{3}{16}$	$\frac{5}{16}$	....	18	0.438	0.150
1	1	$1\frac{1}{16}$	$1\frac{1}{2}$	$\frac{7}{32}$	$\frac{11}{32}$	$\frac{9}{16}$	$\frac{1}{4}$	$\frac{3}{8}$	....	16	0.500	0.170
$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{5}{16}$	$1\frac{7}{8}$	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{5}{8}$	$\frac{9}{32}$	$\frac{3}{8}$	....	16	0.500	0.170
$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{9}{16}$	$2\frac{1}{4}$	$\frac{5}{16}$	$\frac{7}{16}$	$\frac{3}{4}$	$\frac{11}{32}$	$\frac{1}{2}$	....	13	0.625	0.210

All dimensions in inches.

¹ T-slot dimensions will be found in Table 1.² The "width of tongue" in the above table includes the recognized secondary standard having widths *R*₁, the same as the diameter of the corresponding T-bolt. This is to provide for the use, during the transition period, of this standard on many machine-tools where it is already established.³ The "length of tongue" can be varied to suit conditions.TABLE 8—PROPOSED DIMENSIONS FOR COMBINATION REVERSIBLE TONGUES FOR T-SLOTS¹ WITH TWO SIZES OF T-BOLTS AND FOR TWO WIDTHS OF T-SLOTS WITH THE SAME SIZE T-BOLT

Diameter of T-Bolt ²		Tongue Dimensions					Depth of Seat <i>S</i>	Total Thickness Including Tongue <i>K</i>	Height of Shoulder <i>E</i>	Thick-ness of Land <i>C</i>	Screw Dimensions					
Small	Large	Width ²			Length ³ <i>L</i>	Projection <i>P</i>					Diam-eter of Screw <i>D</i>	Number of Screw	Threads per In.	Diam-eter of Head <i>A</i>	Thick-ness of Head <i>G</i>	
		<i>R</i> ₁	<i>R</i>	<i>R</i> ₃												<i>R</i> ₂
$\frac{1}{4}$	$\frac{5}{16}$	$\frac{9}{32}$	$\frac{11}{32}$	$\frac{5}{16}$	$\frac{1}{4}$	$\frac{15}{32}$	$\frac{3}{16}$	$\frac{5}{16}$	$\frac{1}{8}$	$\frac{1}{16}$	0.164	8	32	0.260	0.107	
$\frac{5}{16}$	$\frac{3}{8}$	$\frac{11}{32}$	$\frac{7}{16}$	$\frac{5}{8}$	$\frac{5}{16}$	$\frac{9}{32}$	$\frac{1}{8}$	$\frac{11}{32}$	$\frac{5}{64}$	$\frac{1}{16}$	0.190	10	24	0.303	0.124	
$\frac{3}{8}$	$\frac{1}{2}$	$\frac{7}{16}$	$\frac{9}{16}$	$\frac{3}{2}$	$\frac{5}{8}$	$\frac{5}{4}$	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{5}{32}$	$\frac{1}{16}$	0.250	.....	20	0.375	0.130	
$\frac{1}{2}$	$\frac{5}{8}$	$\frac{9}{16}$	$\frac{11}{16}$	$\frac{5}{4}$	$\frac{3}{2}$	$\frac{15}{16}$	$\frac{1}{8}$	$\frac{9}{32}$	$\frac{13}{32}$	$\frac{3}{32}$	$\frac{3}{32}$	$\frac{1}{4}$	.....	20	0.375	0.130
$\frac{5}{8}$	$\frac{3}{4}$	$\frac{11}{16}$	$\frac{13}{16}$	$\frac{5}{2}$	$\frac{7}{4}$	$1\frac{1}{2}$	$\frac{7}{32}$	$\frac{5}{16}$	$\frac{15}{32}$	$\frac{3}{16}$	$\frac{3}{32}$	$\frac{5}{16}$	.....	18	0.438	0.150
$\frac{3}{4}$	1	$\frac{13}{16}$	$1\frac{1}{16}$	1	$\frac{3}{4}$	$1\frac{1}{2}$	$\frac{7}{32}$	$\frac{1}{8}$	$1\frac{9}{32}$	$\frac{1}{4}$	$\frac{3}{32}$	$\frac{3}{8}$	.....	16	0.500	0.170
1	$1\frac{1}{4}$	$1\frac{1}{16}$	$1\frac{5}{16}$	$1\frac{1}{2}$	1	$1\frac{7}{4}$	$\frac{1}{4}$	$\frac{7}{16}$	$1\frac{1}{16}$	$\frac{9}{32}$	$\frac{1}{8}$	$\frac{3}{8}$	.....	16	0.500	0.170
$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{5}{16}$	$1\frac{9}{16}$	$1\frac{1}{2}$	$1\frac{1}{4}$	$2\frac{1}{4}$	$\frac{5}{16}$	$\frac{1}{2}$	$1\frac{13}{16}$	$\frac{11}{32}$	$\frac{1}{8}$	$\frac{1}{2}$	.....	13	0.625	0.210

All dimensions in inches.

¹ T-slot dimensions will be found in Table 1.² The above table provides for a series of tongues so that a pair of tongues can be used with fixtures to machines of different sizes, using a different size T-bolt, and can also be used with fixtures on different machines having two widths of T-slots for the same size T-bolt.³ The "length of tongue" can be varied to suit conditions.

industries that will have been issued by the Production Division.

The submission of the report to the Society for approval was referred to on p. 432 of the November, 1926, issue of THE JOURNAL, and is printed in full in this issue to give the automotive industries further opportunity to review it before it is finally passed upon by the Standards Committee and Society at the Annual Meeting.

HEAD-LAMP STRENGTH AND RIGIDITY

Tests Proposed for Adoption as Recommended Practice by Lighting Division

At its Semi-Annual Meeting last June the Society adopted specifications governing the construction of head-lamps, as given in the S.A.E. Recommended Practice on p. B9 of the S.A.E. HANDBOOK. At that time the report included a test

for the rigidity of the mounting of head-lamps (Item 10) and a reflection factor (Item 13), but these were not included in the report as adopted as it was felt they should be given further study. The Subdivision subsequently made a further canvass of the industry relative to these items and submitted its report at the meeting of the Lighting Division held in Detroit on Nov. 8.

With regard to the specification for the rigidity of head-lamp mounting, it was felt that two tests should be considered, the first bearing on the rigidity of the head-lamp shell with regard to its mounting device when firmly held, and the second with regard to the head-lamp when mounted on a motor-vehicle in accordance with standard practice.

At the meeting the statement was made that actual tests had been made along the lines proposed by the Subdivision, and that these were considered adequate. The Lighting Division therefore recommends that the following paragraphs be adopted and included in the present S.A.E. Recommended Practice.

With the head-lamp mounting firmly attached to a fixed support, there shall be no permanent distortion of the head-lamp as measured by the deflection of the beam, after a steady pressure of 75 lb. is applied for 1 min. to the upper edge of the door in a direction parallel with the head-lamp axis.

With the head-lamp mounted on the car in accordance with standard practice, there shall be no permanent deflection of the head-lamp beam due to distortion of the head-lamp mounting after applying a steady pressure of 75 lb. for 1 min. at the upper edge of the door in a direction parallel with the head-lamp axis.

With regard to writing a definite specification for the reflection factor of head-lamp reflectors, the Subdivision reported that considerable work had been done toward working out some satisfactory means of specifying what this factor should be but that, due to the many variable factors involved, the various kinds of reflecting surface that are available and the many operating conditions that would have to be considered, to write a definite specification without having much more information and more unanimity of opinion bearing on this subject hardly seems possible. No definite action was therefore taken on it by the Division for the time being.

BASES, SOCKETS AND PLUGS

Lighting Division Recommends Revision of Tolerances in Present Standard

In discussing electric incandescent lamps at the meeting of the Lighting Division in Detroit on Nov. 8, it was pointed out that the tolerances for the distance from the pin in the base to the end of the soldered tip is specified to limits of from 0.240 to 0.299 in. and that, inasmuch as no manufacturers attempt to gage this dimension so accurately as indicated by the upper limit, this dimension might better be specified in the even decimal 0.300 in. This change will also conform to the corresponding dimension on electric incandescent lamps as reported in this issue of THE JOURNAL. The Division therefore recommends that this change be made in the S.A.E. Standard for Bases, Sockets and Plugs on pages B5, B5a and B5b of the S.A.E. HANDBOOK, together with changing the maximum limit on p. B5 from the center of the pin to the soldered tip from 0.219 to 0.220 in.

NEW STANDARD FOR SIGNAL-LAMPS

Subdivision Report on Recommended Practice Approved by Lighting Division

At the meeting of the Lighting Division in May, 1925, the Division was requested to consider standardization of signal-lamps inasmuch as they had come into general use in great variety. The feeling then was that if a standard could be formulated it would clarify the situation that is developing in connection with the State regulation of motor-vehicles. A Subdivision was appointed, consisting of C. D. Ryder, of the Cincinnati-Victor Co., chairman; C. E. Godley, of the Edmunds & Jones Corporation; and H. H. Magdsick, of the National Lamp Works of the General Electric Co. It will investigate the subject and report to the Division. The Automobile Lighting Association, which was recently organized and is particularly interested in lamp standardization, has co-operated with the Subdivision in preparing its report. The Lighting Division at its meeting in Detroit on Nov. 8 reviewed the report and approved it with a few minor modifications in wording to make it conform with other lamp standards of the Society. The Division recommends that the report be adopted as S.A.E. Recommended Practice.

SIGNAL-LAMPS

Signal-lamps, other than those embodying mechanical motion, shall be tested singly and shall meet the following requirements as to light intensity and distribution:

Visibility.—Signal-lamps shall indicate the driver's intention to diminish the speed of, or to stop or to change the direction of a motor-vehicle, by displaying a red light sufficiently bright to attract attention in normal sunlight at a distance of 100 ft. to the rear and 45 deg. to the right and to the left of the vehicle. But signal-lamps shall not project a dangerously glaring or dazzling light.

Light Intensity.—On a line perpendicular to the center of the lamp-face the minimum average brightness shall be 2 cp. per sq. in. over the minimum illuminated area of $3\frac{1}{2}$ sq. in.

At all points at an angle of 30 deg. to the perpendicular to the center of the lamp-face, the minimum average brightness shall be 0.15 cp. per sq. in. over the minimum illuminated area of $3\frac{1}{2}$ sq. in.

In no direction shall the intensity be more than 25 apparent cp.

The Division also recommends that the signal-lamp mounting be the same as the S.A.E. Recommended Practice for Tail-Lamp Mounting, p. B2 of the S.A.E. HANDBOOK, which is by two $\frac{1}{4}$ in.-20 bolts 2 in. apart extending $\frac{1}{2}$ in. from the back of the lamp and on a line horizontal with the plug-socket.

During the discussion at the Division meeting some question arose with regard to whether only a red light should be required or a yellow or amber light should be included in the specification. Inasmuch as most of the signal-lamps in use have the red light and as having practice as nearly uniform as possible is very desirable, the Division felt that the standard as adopted by the Society should indicate the use of but one color.

Controversy has arisen regarding the wording on signal-lamp glasses. The Subdivision is not entirely in agreement on this subject and recommends that the subject not be mentioned in the proposed S.A.E. Recommended Practice. Neither does the Subdivision believe that standardization should be attempted with respect to the position of the signal-lamp relative to the tail-lamp.

REVISED TAIL-LAMP SPECIFICATIONS

Lighting Division Recommendations on Construction and Illumination

When the Lighting Division discussed the subject of signal-lamps as reported elsewhere in this issue of THE JOURNAL, the subject of tail-lamps was also considered for the same general reasons and also in amplification of the present S.A.E. Recommended Practice for Tail-Lamp Illumination as printed on p. B8e of the S.A.E. HANDBOOK. The report of the Subdivision that was considered by the Lighting Division at its meeting in Detroit on Nov. 8 embodies the requirements of the present S.A.E. Recommended Practice and amplifies it with the exception of those parts of the present recommended practice that do not bear on the technical specification. At the meeting of the Division the question of specifying that the tail-lamp give an amber light was also discussed at considerable length in view of the recent agitation to change current practice. It was felt that the ruby lights should be retained. At the meeting the statement was made that the Division's recommendation in this connection conforms with the recommendations of the National Conference on Street and Highway Safety instituted by Secretary of Commerce Herbert Hoover. The Lighting Division therefore recommends the following for adoption in revision of the present S.A.E. Recommended Practice for Tail-Lamp Illumination.

TAIL-LAMPS

Tail-lamps shall be tested singly and shall meet the following requirements as to construction, light intensity and distribution:

Visibility.—Tail-lamps shall display a ruby light at night, plainly visible under normal atmospheric conditions at a distance of 500 ft. from

the rear of the vehicle and shall so illuminate the number-plate carried at the rear of such vehicle as to make it legible at a distance of 50 ft. from the rear of the vehicle.

Construction.—The lamps shall be weather and dustproof and constructed so as to withstand the shock and vibration to which they are ordinarily subjected in use.

Light Intensity.—Tail-lamps shall emit a ruby light which on a line perpendicular to the center of the lamp-face shall be not less than 0.10 apparent cp. and which in all directions at 30 deg. to the perpendicular to the center of the lamp-face shall be not less than 0.05 apparent cp. In no direction shall there be more than 5 apparent cp.

Tail-lamps shall have an opening covered with colorless glass sufficiently large to permit light to cover the entire surface of the registration number-plate, which for the purpose of the test shall be represented by a plane surface 16 in. long by 6½ in. wide in the case of a device for motor-vehicles and 10 in. long by 5 in. wide in the case of a device for motorcycles.

The registration plate holder shall be constructed in such a manner that the major portion of the light incident at any point on the registration plate shall make an angle of not less than 8 deg. with the plane of the plate.

When tested with an incandescent lamp of 2 spherical cp., the illumination as measured on white blotting paper shall be not less than 0.5 foot-candles at any point and the ratio of maximum to minimum intensity shall not exceed 30.

Cut-off of illumination shall not be less than 1½ in. from the plate measured perpendicularly to the plane of the plate at the edge farthest from the lamp.

There must be no unduly bright areas or excessive contrast in the illumination on the registration number-plate.

The Subdivision does not recommend that the American Railway Association's specifications as to color and light transmission be adopted, because of the prohibitive cost of glass so made. The suggestion was made that the Association's specifications might be adopted as to color only, but the Subdivision stated that it does not know of any simple test for determining color.

The members of the Subdivision are C. D. Ryder, of the Cincinnati-Victor Co., chairman; C. E. Godley, of the Edmunds & Jones Corporation, and H. H. Magdick, of the National Lamp Works of the General Electric Co.

CRANKCASE DRAIN-PLUGS REVISED

Engine Division Adds Two Sizes to Present Recommended Practice and Drops One

Following a survey of practice with regard to the dimensions of shanks on crankcase drain-plugs, the Engine Division has recommended that the present S.A.E. Recommended Practice, p. A3b of the S.A.E. HANDBOOK, be completed by including a 1½-in. hexagon shank for the ¾-in.-18 straight-threaded plugs and a 7/16-in. square shank for the ½-in. taper pipe-thread plugs. The Division appreciated that in a number of instances plugs are used which have a wrench-hole instead of a shank, but felt that this type of plug is undesirable because of the difficulty of removing it without a special wrench and because the usual practice of mechanics is to remove these plugs with a pair of pliers, thus destroying the thread. The suggestion was made that the recommended practice included a standard connection for drain-cocks, but the Division decided not to make such a recommendation because drain-cocks are too liable to be broken off by obstructions on the road. The Division also recommends that the ¾-in. taper pipe-plug

be omitted as it is considered too small for good practice in that it restricts the rush of oil out of the crankcase when draining it.

CHANGE IN MANGANESE LIMITS

Iron and Steel Division Revises Specification for S. A. E. Steel 1046

S. A. E. Steel 1046, which was added to the Society's steel specifications at the request of the American Gear Manufacturers Association and is used solely by gear manufacturers, was the subject of discussion at the last meeting of the Iron and Steel Division held in the offices of the Society on Nov. 23.

The use of this steel for street-car gears has developed the need for revised limits for the manganese content and the combined carbon and manganese-content.

S. P. Rockwell, as representative of the American Gear Manufacturers Association, after reading a summary of the opinions of gear users favoring the change, requested that the Division consider recommending manganese-content limits of 0.40 to 0.60 per cent and the addition of a specification calling for a combined carbon and manganese-content limit of 0.85 to 1.05 per cent. This brought up a question of policy regarding the admission to S. A. E. Steel Standards of specifications for a steel that was only used for a specific purpose. In this instance the steel under consideration is not an automotive steel, and the Division felt that it was inadvisable, from a precedent standpoint, to follow so closely the requirements of a given industry. To change the specifications as requested would introduce a limit on the combined content of carbon and manganese, which is a factor not appearing elsewhere in any of the S. A. E. Steel Specifications. It was, therefore, voted to recommend a change in the manganese range only, from 0.30 to 0.50 per cent to 0.40 to 0.60. The proposed standard follows:

Carbon Range, per cent	0.40-0.50
Manganese Range, per cent	0.40-0.60
Phosphorous Maximum, per cent	0.045
Sulphur Maximum, per cent	0.050

The phosphorus and the sulphur content are subject to consideration by a subdivision to be appointed for the investigation of phosphorus and sulphur limits in S. A. E. Steels.

NEW IRON AND STEEL SUBDIVISIONS

Groups on Chemical Compositions and Malleable Iron To Be Appointed

The proposed changes in phosphorus and sulphur-content limits, as shown in the table on p. 451 of the November issue of THE JOURNAL, brought forth such a divergence of opinion regarding the advisability of such changes that the Iron and Steel Division voted at its meeting, which was held in New York City on Nov. 23, to appoint a subdivision to investigate the entire subject further.

It was also voted that study should be given by the subdivision to eliminating from consideration any change in the phosphorus-content limits, the advisability of changing the sulphur-content limits only to be the principal subject taken up. In view of the fact that few expressions of opinion had been received from consumers, the suggestion was made that the subdivision prepare for publication in THE JOURNAL some articles to give widespread publicity to the proposed changes. An attempt will be made by members of the Subdivision to discuss with objectors to the new limits their reasons for complaint and to submit a comprehensive report before the next meeting of the Division.

The Subdivision will coordinate its work with that of the Joint Committee of the American Society for Testing Materials and this Society, which is working on phosphorus and sulphur limits in general, and will take into

consideration the work done by the Bureau of Standards on this subject.

W. C. Peterson, in a verbal report of the Subdivision on Sheet Steel, pointed out the impossibility of settling on a basis for tests for sheet steel. This decision was reached after a canvass of sheet-steel users to obtain their recommendations for testing. These varied widely in those few companies which use a laboratory method of testing. The report recommends that sheet-steel thickness be specified by decimals rather than by any of the gages now in use. This matter will be considered further at the next meeting of the Division.

After discussion on the higher limits for malleable-iron castings approved by the American Society for Testing Materials and the American Malleable Castings Association, the Division voted to appoint a subdivision to determine the advisability of recommending two specifications for malleable-iron castings to conform to the practice that is now in existence of using two grades of castings. At the present time, in addition to the certified grade, a grade of malleable-iron casting is in use, which is slightly better than gray iron, and as this latter has a definite place in production the subdivision will undertake the consideration of specifications for both grades.

S.A.E. STEELS 2015 AND 2115

Division Confirmation of Letter-Ballot on Nickel-Steel Compositions

The Iron and Steel Division at a meeting held in the offices of the Society on Nov. 23, confirmed the letter-ballot approving the proposed compositions of S.A.E. Steels 2015 and 2115, details of which were printed in the table of proposed S.A.E. Standard iron and steel chemical compositions on p. 451 of the November issue of THE JOURNAL. These steels contain 0.50 and 1.50 per cent of nickel respectively and have been approved with the understanding that they will be subject to consideration of the phosphorus and sulphur content which will be investigated by a subdivision to be appointed by Chairman Watson for the purpose of preparing an exhaustive report on phosphorous and sulphur content in S.A.E. Steels.

An account of the action leading to the appointing of this subdivision will be found in an article on the activities of the Iron and Steel Division.

WIRING COLOR-CODE RECOMMENDED

Electrical Equipment Division Approves Subdivision Report for Wire Colors

The first tentative report of the Subdivision that was organized to prepare a color code for electrical wiring in motor-vehicles was published on p. 571 of the June, 1926, issue of THE JOURNAL. Several constructive criticisms of the preliminary report were received and the Subdivision redrafted the proposal and again circularized it. Information in the hands of the Electrical Equipment Division at its meeting on Nov. 9 indicated that, although there are still some criticisms of the proposal, it meets with general approval and in fact forms a basis for wiring systems recently adopted by some of the automobile companies. The Division felt that the report is now in good form and has recommended it for adoption by the Society as S.A.E. Recommended Practice. The report follows:

PASSENGER-CAR WIRING COLOR-SCHEME FOR USE WHERE CABLE IS BOUGHT IN COILS RED (Unprotected Live Wires)

Generator to Cut-Out or Regulator
Cut-Out or Regulator to Ammeter
Ammeter to Battery
Ammeter to Overload Breaker or Fuse

Low-Tension or Primary Ignition
All Other Unprotected Live Wires

YELLOW (Protected Live Wires)

Horn Feed Wire
Signal-Lamp Switch Feed Wire
Body-Lighting Switch Feed Wires
Protective Devices to Lighting Switches
All Other Protected Live Wires

PASSENGER-CAR WIRING COLOR-SCHEME FOR USE WHERE CABLE IS BOUGHT IN FORM OF HARNESS

RED (Unprotected Live Wires)

Generator to Cut-Out or Regulator
Cut-Out or Regulator to Ammeter
Ammeter to Overload Breaker or Fuse
All Other Unprotected Live Wires

RED WITH YELLOW TRACER

Low-Tension or Primary Ignition

RED WITH BLACK TRACER

Ammeter to Battery

YELLOW (Protected Live Wires)

Horn Feed Wire
Signal-Lamp Switch Feed Wire
Body-Lighting Switch Feed Wires
Protective Devices to Lighting Switches
All Other Protected Live Wires

BROWN WITH BLACK TRACER

Lighting Switch to Junction Block (Parking Lamp)
All Ground Connections (except Battery Ground)

BLACK

Lighting Switch to Tail-Lamp

BLACK WITH RED TRACER

Bright Head-Lamps (or Upper Beam)

GREEN

Dim Head-Lamps (or Lower Beam)
Signal-Lamps (Switch to Lamp)

MOTORCOACH AND TRUCK WIRING COLOR-SCHEME¹ RED (Unprotected Live Wires)

Generator to Cut-Out or Regulator
Cut-Out or Regulator to Ammeter
Ammeter to Battery
Ammeter to Overload Breaker or Fuse
Low-Tension or Primary Ignition
All Other Unprotected Live Wires

YELLOW (Protected Live Wires)

Horn Feed Wire
Signal-Lamp Switch Feed Wire
Body-Lighting Switch Feed Wires
Protective Devices to Lighting Switches
All Other Protected Live Wires

BROWN WITH BLACK TRACER

Generator to Cut-Out or Regulator (Ground)
All Ground Connections (except Battery Ground)

BLACK

Bright Head-Lamps (or Upper Beam)
Body-Lamp Feed Wires (Switch to Lamp)

BLACK WITH RED TRACER

Dim Head-Lamps (or Lower Beam)
Tail-Lamp

GREEN

Signal-Lamp (Switch to Lamp)
Signal-Lamp (to Indicator or Pilot)

¹It is assumed that motorcoach and motor-truck builders will buy cable in bulk.

FLYWHEEL-HOUSING STANDARD CLARIFIED

Wording of Footnotes Changed by Transmission Division To End Confusion

At the meeting of the Transmission Division, which was held in conjunction with the Engine Division at Detroit on Nov. 11, the notes in the S. A. E. Standard for Flywheels and Flywheel Housings, p. A1 of the S. A. E. HANDBOOK, were revised to read "indicated runout" instead of "indicator reading," inasmuch as the present expression has led to confusion in a number of instances. The other minor correction in these notes that was approved was omitting the cipher in the fourth place of decimals so that the notes would be interpreted as indicating measured accuracy within three decimal places rather than four.

The transmission manufacturers discussed with the engine builders the possibility of still further reducing the tolerances on the bore of the S. A. E. Standard flywheel housings to obviate trouble frequently experienced with clutches that drop out of alignment with the crankshaft due to oversize or warped flywheel housings. The subject was discussed at considerable length, the members of the Division describing the extreme care that is taken in machining the housings as accurately as possible. They felt that decreasing the present standard limits would add materially to the difficulty of this machining operation and the cost of the work. It was finally decided that the Standards Department would conduct a further investigation of this source of trouble in the industry, for consideration by the Transmission and Engine Divisions at a future time.

ROCKWELL HARDNESS-TESTS APPROVED

The Iron and Steel Division at its meeting that was held on Nov. 23 at New York City confirmed the letter-ballot approving the recommendation of the Rockwell Hardness-Tests with the understanding that some minor changes in the wording are to be made by S. P. Rockwell before final recommendations are made to the Standards Committee.

ELECTRICAL EQUIPMENT DIVISION MEETS

Recommendations Approved for Submission to the Standards Committee in January

To complete as much as possible of its work for this year, a meeting of the Electrical Equipment Division was held in Detroit on Nov. 9. Several definite recommendations were made and reports of progress received on a number of other subjects. The action taken by the Division on automobile wiring, instrument mountings, ground-return wiring system, and additions to the electrical equipment nomenclature are reported elsewhere in this issue of THE JOURNAL.

A Subdivision has been working on the standardization of distributor nipples that are used to prevent water from running along the ignition cables into the timer-distributor head. A tentative report was considered at the Division meeting, but no definite action was taken other than to request further consideration along the lines of suggestions made at the meeting with regard to detail dimensions.

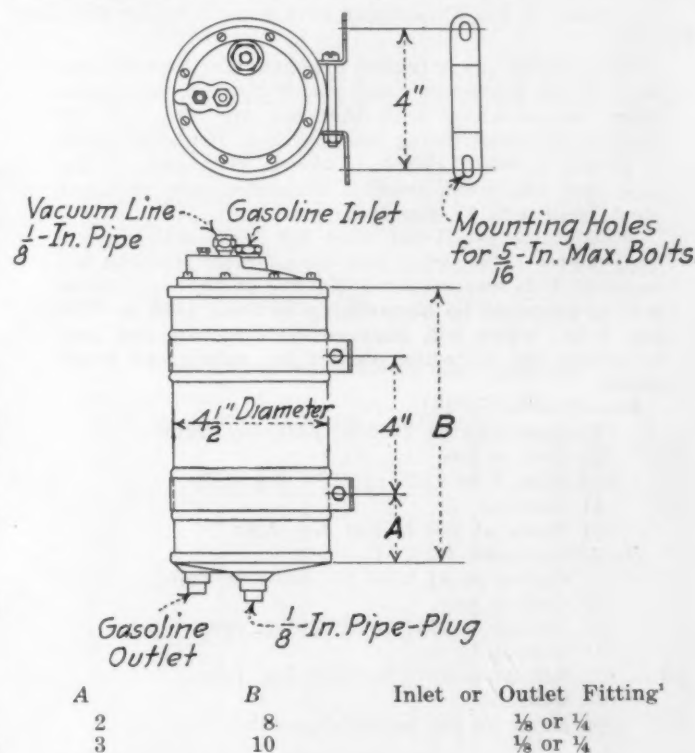
It was decided to take no further action toward revising the present standard for Fuses and Fuse Clips, printed on p. B32 of the S. A. E. HANDBOOK, inasmuch as an investigation of the use of the present standard with reference to motorcoach installations indicated that the standard is satisfactory. Work has been in progress for some time in connection with developing suitable electrical tests for insulated

cable, but, as this has not been completed, no recommendations have been made by the Division.

Those in attendance at the meeting were T. L. Lee, of the North East Electric Co., chairman; H. E. Adams, of the W. G. Nagel Electric Co.; K. P. Anspack (representing T. E. Wagar), of the Studebaker Corporation; G. D. Becker, of the Underwriters' Laboratories; C. J. Bopp, of the Packard Motor Car Co.; W. B. Churcher, of the White Motor Co.; G. A. Delaney, of the Paige-Detroit Motor Car Co.; W. S. Haggott, of the Packard Electric Co.; A. E. Jacobs, of the King-Seeley Corporation; W. M. Scott, of the Sterling Manufacturing Co.; B. M. Smarr, of the General Motors Corporation; J. E. White, of the Chrysler Corporation, and R. S. Burnett, standards manager of the Society.

FUEL VACUUM-TANK MOUNTINGS REVISED

The accompanying specification for fuel vacuum-tank mountings, constituting a revision of the present S.A.E. Standard on p. C45 of the S.A.E. HANDBOOK, has been submitted by F. G. Whittington of the Stewart-Warner Speedometer Corporation to bring the standard up to date. It will be presented for final Division action at the Nov. 15 meeting of the Parts and Fittings Division.



¹ American Standard taper pipe threads.

CLUTCH NOMENCLATURE REVISED

Transmission Division Recommends Slight Changes in the Present Standard

The Transmission Division at its meeting in Detroit on Nov. 11 voted to recommend that the nomenclature on p. K11 of the S. A. E. HANDBOOK be revised by changing the term "Clutch shaft bearing (not in transmission case)" to read "Clutch pilot bearing (in flywheel)" under Group 1 of Division X, and to substitute the word "yoke" for "fork" in Group 2 of Division X.

Members of the Division stated that considerable trouble is experienced from the driving-drum of multiple-disc clutches getting out-of-round and the suggestion was made that the present usual tolerance of 0.002 in. be increased to 0.004 in. It was decided, however, that before a definite

recommendation is made, the Standards Department should circularize the industry as to establishing limits of 11.495 to 11.499 in. for the drum diameter, and 13/32 as the dimension for the diameter of the bolt-holes and as to the number of bolts and the bolt-circle diameter.

Those in attendance at the Division meeting were S. O. White, of the Warner Gear Co., chairman; L. C. Fuller, of Fuller & Sons Mfg. Co.; D. E. Gamble, of the Borg & Beck Co.; J. J. Morris, of the Rockford Drilling Machine Co.; H. W. Sweet, of the Brown-Lipe Gear Co., and C. E. Swenson, of the Mechanics Machine Co.

PROPOSED NEW HEAT-TREATMENTS

Subdivision Recommends Heat-Treatments and Notes for S.A.E. Steel 4615

At a meeting of the Iron and Steel Division held in the offices of the Society on Nov. 23, the Subdivision on Physical-Property Charts recommended, for approval as general information, notes and heat-treatments for S.A.E. Steel 4615. The usage of the other molybdenum steels has been insufficient to permit the recommendation of similar data for them; it was, accordingly, decided to recommend heat-treatments for S.A.E. Steel 4615 only at this time.

The report of the Subdivision as approved by the Division follows:

These steels are intended primarily for case-hardening. When maximum hardness of the case and maximum refinement of both the case and the core are desired, distortion being unimportant, Heat-Treatment V should be used. When hardness, refinement of the case and the least possible distortion are required, Heat-Treatment IV should be used.

When these steels are used for gears for which a high degree of accuracy and considerable strength are required, it is recommended that the carburizing operation be preceded by normalizing at from 1650 to 1750 deg. fahr., which will improve the structure and tend to reduce the distortion caused by subsequent treatments.

Heat-Treatment 4615—IV

- (1) Carburize at 1600 to 1650 deg. fahr.
- (2) Cool in box
- (3) Reheat to 1475 to 1525 deg. fahr.
- (4) Quench
- (5) Draw at 250 to 500 deg. fahr.

Heat-Treatment 4615—V

- (1) Carburize at 1600 to 1650 deg. fahr.
- (2) Cool in box
- (3) Reheat to 1525 to 1575 deg. fahr.
- (4) Quench in oil
- (5) Reheat to 1375 to 1425 deg. fahr.
- (6) Quench
- (7) Draw at 250 to 500 deg. fahr.

NEW ENGINE-TESTING FORMS

Proposed Charts Will Be Applicable to All Internal-Combustion Engine Types

The present S.A.E. Standard for Engine-Testing Forms on p. A51 of the S.A.E. HANDBOOK, which was adopted by the Society in 1917 and revised in 1924, is used very extensively although the complete forms are suitable for only a limited range of engines. The Engine Division has undertaken a complete review of the forms and a rearrangement and extension of them, particularly the curve sheet, so that they can be used more readily for all common types and sizes of internal-combustion engine. A Subdivision was appointed consisting of L. P. Kalb of the Continental Motors Corporation, chairman; L. S. Keilholtz, of the Delco Light Co.; E. T. Larkin, of the Sterling Engine Co.; L. K. Marshall, of the General Motors Corporation Research Laboratories; A. W. Pope, Jr., of the Waukesha Motor Co.; and Prof. O. W.

Sjogren, of the University of Nebraska. This Subdivision made a careful study of the present forms and proposed a number of changes in and extensions of them. The report of the Subdivision was carefully reviewed by the Engine Division at its meeting in Detroit on Nov. 11, and approved with the recommendation that the following revisions be made in the present S.A.E. Standard.

RULES AND DIRECTIONS—SHEET A

In the fourth paragraph following the heading General Rules and Directions, the word "torque" in next to the last line is changed to "horsepower."

Under General Rules and Directions, the following paragraph is to be added immediately following the paragraphs under Indicated Horsepower.

Correction Factors.—All results shall be corrected to a standard barometric pressure of 29.92 in. of mercury and a standard temperature of 520 deg. fahr. absolute, which is the same as 60 deg. fahr. These corrections are to be made by using the correction formula.

The form of the correction formula printed at the end of Sheet A is to be clarified by extending the radical sign over the entire term T_o/T_s and changing the wording in the key to P_s to read

Standard barometric pressure of 29.92 in. of mercury.

The key to T_s is changed to read

Standard absolute temperature of 520 deg. fahr.

The correction formula and key are to be transposed to follow the new paragraph on Correction Factors.

In the first paragraph following the subheading Specification Sheet, the words "or kerosene" are omitted at the end of the fifth line and the speeds "100 to 120 r.p.m." in the last line of the paragraph are changed to read "speed of maximum torque."

SPECIFICATION SHEET—B

No changes are proposed in this sheet.

LOG SHEET—C

This sheet is to be turned on the page so that it will read from top to bottom uniformly with the other three sheets. Provision for recording the room temperature and barometric reading has been made in the body of the sheet and these items should therefore be omitted from the upper right-hand corner of the sheet. The following changes and additions have been made to items under Brake Horsepower and Fuel Consumption.

Add the word "Observed" to "Torque in Lb.-Ft."

Add the term "Torque Corrected" immediately following the above.

Add "Observed" to the item "Brake Horsepower."

Add "Brake Horsepower Corrected" immediately following the above.

Add "Observed" to the term "Indicated Horsepower."

Add "Indicated Horsepower Corrected" immediately following the above.

Immediately following "Temp. Jacket Water—Out" add the three items in the order given.

- (1) Temperature of oil in, deg. fahr.
- (2) Temperature of oil out, deg. fahr.
- (3) Oil pressure, lb.

Immediately following "Temp. Air to Carb." include the item "Room Temp. deg. fahr."

Immediately following the last item "Thermal Eff. re B. Hp. add the term "Barometer, In. Hg."

Leave two blank spaces following this group of items and two or more blank spaces following the group of items under "Friction HP."

Omit from the bottom of the sheet the sentence beginning "If readings are corrected to 60 deg. fahr."

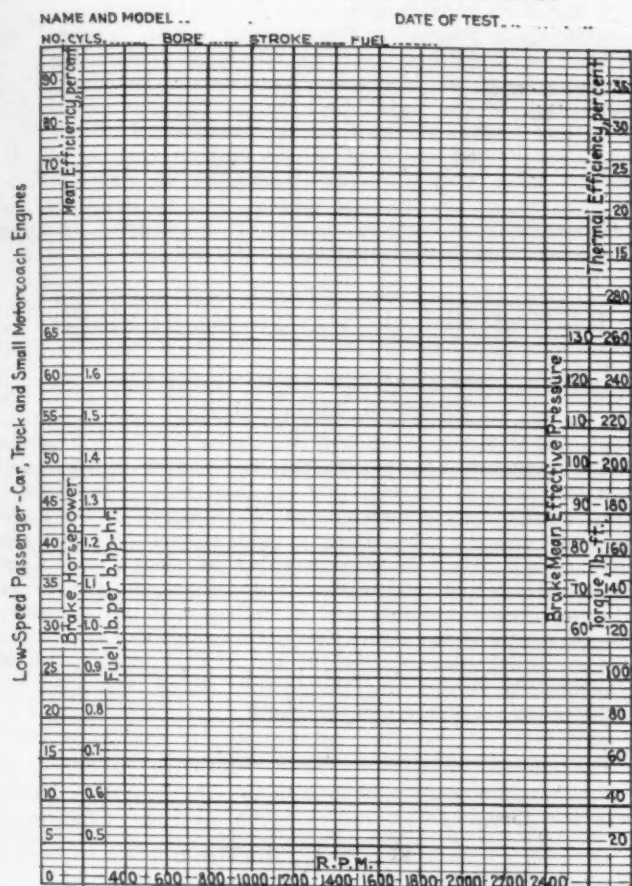
CURVE SHEETS—D1 TO D6

Experience in plotting engine curves on the present Standard curve-sheet has shown that the sheet is inadequate

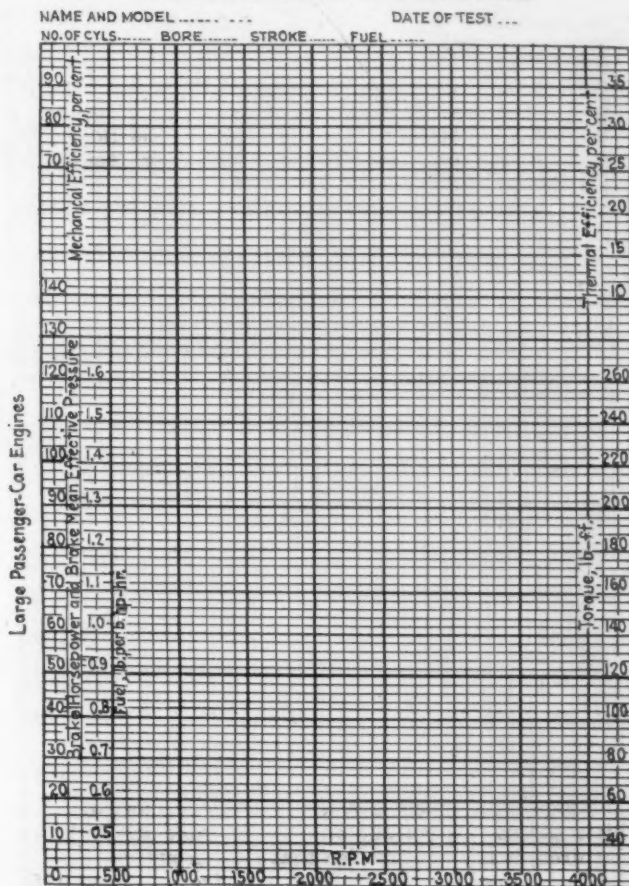
STANDARDIZATION ACTIVITIES

557

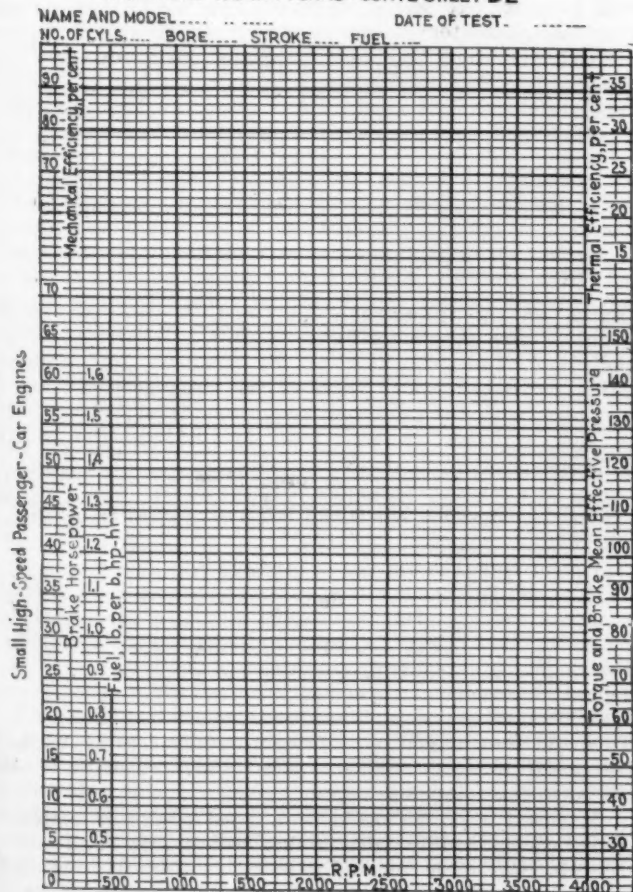
S.A.E. ENGINE TESTING FORMS-CURVE SHEET D1



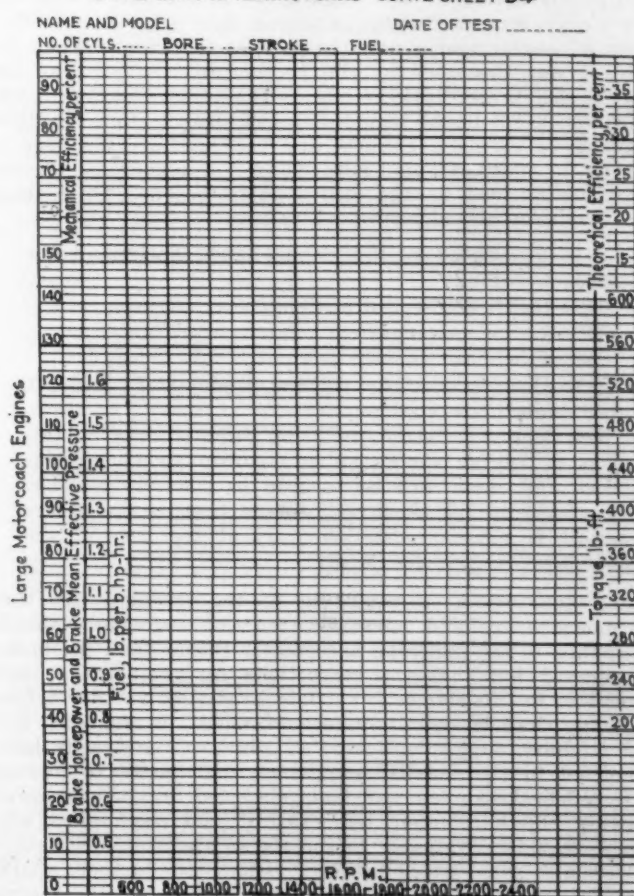
S.A.E. ENGINE TESTING FORMS-CURVE SHEET D3

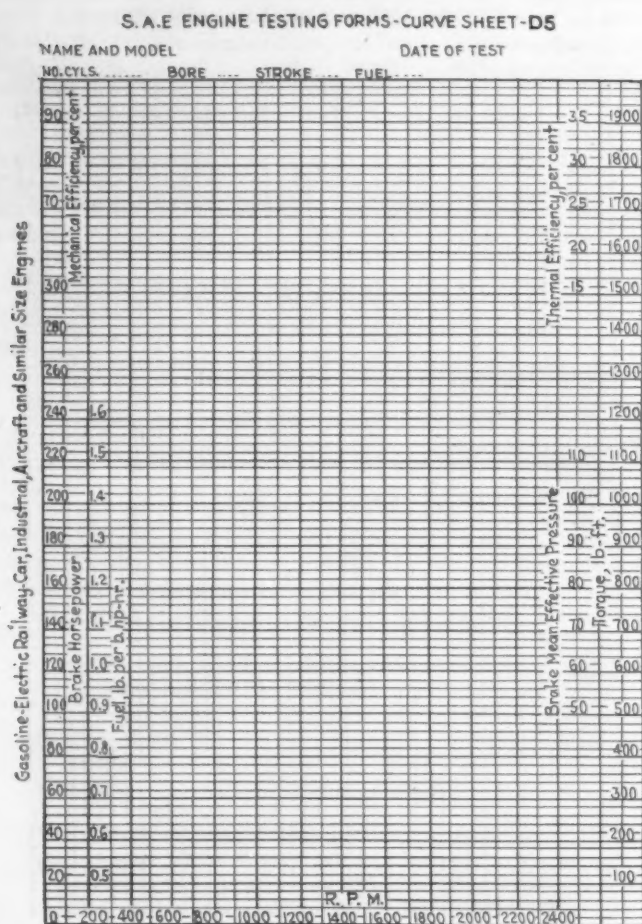


S.A.E. ENGINE TESTING FORMS-CURVE SHEET D2



S.A.E. ENGINE TESTING FORMS-CURVE SHEET D4





and poorly arranged with regard to the ordinate scales and the Subdivision therefore arranged five general classifications of engine and a new curve-sheet for each. When the subject was discussed by the Engine Division, it was felt that a still larger type of engine than provided for by the Subdivision should be included in the classification for high-horsepower airplane engines and the heavier-duty type of engine for industrial and motive-power applications. It was therefore decided to add still another curve-sheet, making six sheets in all, classified as follows:

- D1—Low-speed passenger-car, truck and small motorcoach engines
- D2—Small high-speed passenger-car engines
- D3—Large passenger-car engines
- D4—Large motorcoach engines
- D5—Gasoline-electric rail-car, industrial, aircraft, and similar size engines.

D6—The Subdivision felt that further data on this class of engine should be had before preparing this sheet and these will be secured as soon as possible. The form of the sheet will follow that of the others and it is hoped it can be ready at the time of the Standards Committee Meeting

The Subdivision in reporting to the Division felt that the temperature and barometric correction-formula should be applied to the indicated horsepower rather than the brake horsepower but that the corrections for temperature and barometer in this connection should be studied further before a change shall be definitely recommended. It was also felt that a chart, suggested forms of which have already been submitted to the Subdivision, which will facilitate finding corrected brake-horsepower from observed brake-horsepower knowing the barometer, temperature and mechanical efficiency, would be valuable to include in the forms, but this matter also was left by the Division for further study. The Division expects to take these points up with the engine

and car builders, as well as with the Bureau of Standards which has done considerable work in this connection.

Among those present at the meeting of the Engine Division were A. F. Milbrath, of the Wisconsin Motor Mfg. Co., chairman; G. H. E. Berthold (member of the Spark-Plug Subdivision), of the Rajah Co.; Gustaf Carvelli (representing Arthur Nutt), of the Curtiss Aeroplane & Motor Co.; S. R. Castor (representing E. S. Marks), of the H. H. Franklin Mfg. Co.; G. Walker Gilmer, of Philadelphia; E. T. Larkin, of the Sterling Engine Co.; L. R. Nagler, of the General Motors Corporation; and R. S. Burnett, manager of the Standards Department of the Society.

RADIATOR LACINGS TO BE REVISED

Subdivision Circularizes the Industry for Comments on Proposed Specifications

The present S.A.E. Standard for Radiators, p. A27 of the S.A.E. HANDBOOK, specifies that radiator hood-lacings shall be not less than $\frac{3}{8}$ in. wide and not less than $\frac{1}{8}$ in. thick.

As it is felt by the members of the Subdivision on Radiators that definite dimensions should be specified for the lacings to simplify the large number of sizes being used, the Society collected information on the dimensional practice of the automobile builders and submitted a detail summary to the members of the Subdivision, this summary giving the thickness, width and material of the lacings used by all of the automobile companies, the lacings being arranged according to the thickness and the width.

A tabulation of the sizes included in this summary, Table 1, shows that 37 different sizes are used.

TABLE 1—TABULATION OF RADIATOR LACINGS USED IN CURRENT PRACTICE

Thickness, In.	Width, In.															
	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{13}{16}$	$\frac{7}{8}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{3}{4}$	2	$2\frac{1}{4}$
$\frac{1}{16}$...	3	...	2	1	...	5	...	1	...	...	...	...	...	...	...
$\frac{3}{32}$	2	1	4	...	1	2	1	1	...	1	...	...	...	...
$\frac{1}{4}$...	1	1	7	7	1	7	16	...	6	8	...	2	...	...	...
$\frac{5}{16}$	1	1	2	...	2	...	1	...	...	...	...	...	1	...
$\frac{3}{8}$	1	...	...	1	...	1	1	...	...	...	...	...	...
$\frac{1}{2}$	1	...	...	1	...	...	...	...	...	...	...	...
$\frac{5}{8}$
$\frac{3}{4}$
$\frac{7}{8}$
1
$1\frac{1}{8}$
$1\frac{1}{4}$
$1\frac{1}{2}$
$1\frac{3}{4}$
2
$2\frac{1}{4}$

* Sizes selected as standard.

Based on the information obtained, a tentative recommendation was drawn up by J. D. Harris, chairman of the Subdivision, and submitted to the members for comment. In this recommendation, Table 2, the sizes proposed are in accordance with the minimum requirements of the specification for radiator lacings now printed in the S.A.E. HANDBOOK.

TABLE 2—PROPOSED STANDARD SIZES OF RADIATOR LACING

Thickness, In.	Width, In.					
	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	1	$1\frac{1}{4}$
$\frac{1}{8}$	X	X	X	X	X	X
$\frac{3}{16}$	..	X	X	X	X	X

To avoid the danger of improper material being used, it is proposed to cover the character and treatment of the material in the following manner:

Material shall be made of a good grade of cotton yarn woven solidly with a fine weave. It shall not contain jute. The finished webbing shall be thoroughly impregnated with a light solution of creosote or as-

phaltum cut in a solvent deodorized as much as possible. The finished lacing shall be flexible and shall retain its flexibility and resiliency.

It is believed that such a specification will permit the use of good material at a reasonable price. Comments on the proposed list of sizes should be sent to the Standards Department of the Society.

BRAKE NOMENCLATURE EXTENDED

Axle and Wheels Division Proposes Nomenclature Covering Four-Wheel Brakes

Some time ago the suggestion was made that the present S.A.E. Automobile Nomenclature for Wheels, p. K18 of the S.A.E. HANDBOOK, be extended to include reference to four-wheel brake-drums inasmuch as four-wheel brakes had become very extensively used on automobiles. The suggested addition to the nomenclature was referred to the Division members and has been approved by them with the recommendation that it be incorporated in the present standard as follows:

On p. K18 of the S.A.E. HANDBOOK, under Division XV, Group 1, following the last item, include "Front-wheel brake-drums (if front-wheel brakes are used)".

Under Group 2 for rear wheels, change the term "Wheel brake-drums" to read "Rear-wheel brake-drum".

FOCUSING TYPE INCANDESCENT LAMPS

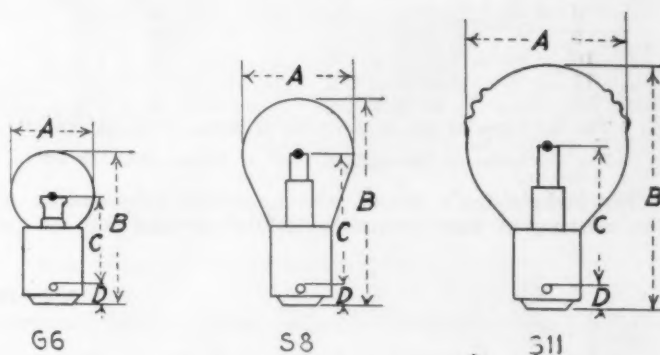
Revision of Present S.A.E. Standard Recommended by Lighting Division

Last spring a subdivision of the Lighting Division was appointed to review the S.A.E. Standard on Electric Incandescent Lamps of the focusing type, p. B4 of the S.A.E. HANDBOOK, in view of recent developments in lamps and the introduction of the depressed-beam or two-filament type of head-lamp. A thorough study of the subject has been made by the Subdivision which reported its recommendations at the meeting of the Lighting Division, held in Detroit on Nov. 8. It was also reported that the members of the Division who had previously cast a letter-ballot on the report had approved it. Several suggestions that had been submitted by other members were discussed and included in the recommendations. One of the principal points in connection with the report that was considered related to converting the tolerance of the light-center length and axial alignment for headlight lamps from 3/64 in. to the decimal form. It was explained that the lamp manufacturers have all made this change. It was finally decided that the conversion should be made to the nearest three-point decimal value, thus converting the 3/64-in. tolerance to 0.047 in. The advisability of placing dimensions on the corrugations of the glass bulbs, which has been included in the Subdivision's report, was considered carefully and the conclusion reached that the actual form of the corrugations is not important so long as they are sufficient to break up the filament image. It was also considered too difficult and impractical to include these detail dimensions in the standard. The note relating to the corrugations was, however, added in the text of the report as given below. The form of the Subdivision's report was also modified by reducing the number of illustrations of types of incandescent lamps and giving their dimensions in tabular form.

It was felt that a valuable supplement to the standard would be a table listing the several incandescent lamps in commercial use, giving their candlepower, voltage, maximum amperage, and other information. The dimensions of the standard lamps are included in the table given below, which is intended only for general information to serve as a guide to the vehicle designer in selecting lamps.

The Lighting Division, therefore, submits the following report with the recommendation that it be adopted in revision

of the present S.A.E. Standard for the Focusing Type of Electric Incandescent Lamp.



ELECTRIC INCANDESCENT LAMPS

Dimension	G-6	G-8	S-8	G-10	S-11 ^a
A	3/4	1	1	1 1/4	1 3/8
B	1 7/16	1 3/4	2	2 1/8	2 3/8
C	3/4	7/8	1 1/8	1 1/8	1 1/4
D	0.300	0.300	0.300	0.300	0.300

Maximum

^a The corrugations on electric incandescent lamps for headlight service shall be of sufficient depth to break up the filament image.

The spacing between the filaments of the depressed-beam or two-filament type of incandescent lamp shall be 0.140 in. \pm 0.016 in.

¹ Light-center length and axial alignment tolerances for headlight lamps are \pm 0.047 in.

ELECTRIC INCANDESCENT LAMP DATA

General Information

Candle-Power	Voltage	Maximum Amperage ²	Bayonet-Base Contact ³	Bulb Type	Bulb Diameter, In.	Maximum Over-All Length, In.	Light Center Length, In.	Filament Form ⁴
2	3-4	1.00	S or D	G-6	3/8	1 7/8	1 3/8	C-2
3	6-8	0.75	S or D	G-6	3/8	1 7/8	1 3/8	C-2
3	12-16	0.50	S or D	G-6	3/8	1 7/8	1 3/8	C-2
3	18-24	0.25	S or D	G-6	3/8	1 7/8	1 3/8	C-2
6	6-8	1.25	S or D	G-8	1	1 3/4	1 3/8	C-2
6	12-16	0.75	S or D	G-8	1	1 3/4	1 3/8	C-2
6	40-44	0.25	D	G-10	1 1/4	2 1/8	1 3/8	C-5
15	6-8	2.00	S or D	S-8	1	2	1 3/8	C-2
15	12-16	1.25	S or D	S-8	1	2	1 3/8	C-2
21	6-8	(3.00)	D	S-11	1 3/8	2 3/8	(1 3/8)	C-2
21		(3.00)					(1 3/8)	C-2
21	6-8	3.00	S or D	S-11	1 3/8	2 3/8	1 3/8	C-2
21	12-16	1.50	S or D	S-11	1 3/8	2 3/8	1 3/8	C-2
21	40-44	0.50	D	S-11	1 3/8	2 3/8	1 3/8	C-13
21	6-8	(3.00)	D	S-11	1 3/8	2 3/8	1 3/8	C-2
21		(0.75)		S-11	1 3/8	2 3/8		C-12
27	18-24	1.25	D	S-11	1 3/8	2 3/8	1 3/8	C-2
32	6-8	4.00	S or D	S-11	1 3/8	2 3/8	1 3/8	C-2
32	12-16	2.00	S or D	S-11	1 3/8	2 3/8	1 3/8	C-2

² Improvements in lamp design and manufacture from time to time make possible changes in ampere ratings. The figures given are therefore maximum and are for use in calculating wire sizes and battery capacities. For test purposes the exact amperage should be obtained from the lamp manufacturer.

³ S—Single-contact. D—Double-contact.

⁴ C indicates a coiled-wire filament.

REVISION OF CLUTCH-FACING SIZES

Subdivision Reports Revised and Extended List for Single-Plate Clutches

At the time the present S.A.E. Recommended Practice for Single-Plate Clutch Facings was adopted, it was hoped that the sizes approved would come into general practice.

However, a recent survey indicated the desirability of revising the specification. A Subdivision of the Transmission Division was therefore appointed, the members thereof being D. E. Gamble, of the Borg & Beck Co., chairman; J. J. Morris, of the Rockford Drilling Machine Co.; and E. E. Wemp, of the Long Mfg. Co. At a meeting of the Subdivision, which was held in Detroit on Nov. 11 prior to the meeting of the Transmission Division, current practice was reviewed and the following revision proposed:

Nominal Size, In.	Diameters, In.	
	Woven Type	Molded Type
8	$7\frac{1}{2} \times 5\frac{1}{2}$	$7\frac{1}{2} \times 5\frac{1}{2}$
9	$8\frac{3}{8} \times 6\frac{1}{8}$	$8\frac{3}{8} \times 5\frac{3}{8}$
10	$9\frac{1}{2} \times 6\frac{1}{2}$	$9\frac{1}{2} \times 6\frac{1}{4}$
11	$10\frac{1}{2} \times 6\frac{3}{4}$	$10\frac{1}{2} \times 6\frac{1}{2}$
12	$11\frac{1}{2} \times 7\frac{1}{4}$	$11\frac{1}{2} \times 6\frac{3}{4}$

The thickness of the woven type of facing shall be $1/8$ or $5/32 \pm 0.005$ in.

The thickness of the molded type of facing shall be $9/64 \pm 0.005$ in.

The Subdivision's report was approved unanimously at the meeting of the Transmission Division and will be re-

ported to the meeting of the Standards Committee in January with the recommendation that it be adopted as a revision of the present S.A.E. Recommended Practice given on p. E19 of the S.A.E. HANDBOOK.

SET-SCREW HEADS AND JAM NUTS

Screw Threads Division Submits Tables for Approval as S.A.E. Standard

After the Society had approved the present S.A.E. Standard for Wrench-Head Bolts and Nuts and Wrench Openings last June, Table 4, for Set-Screw Heads, p. C6c, and Table 7, for Finished and Semi-Finished Jam Nuts, p. C6f, were included in the S.A.E. HANDBOOK as General Information only, as they had not been regularly approved with the rest of the report.

The complete report, as acted on by the Society at that time, and Tables 4 and 7 were taken from the report of the Sectional Committee on the Standardization of Bolt, Nut

TABLE 4—SET-SCREW HEADS

DIAMETER OF SCREW		WIDTH ACROSS FLATS			HEIGHT		
Nominal	Maximum	Nominal	Maximum	Minimum	Nominal	Maximum	Minimum
$\frac{1}{4}$	0.2500	$\frac{1}{4}$	0.2500	0.241	$\frac{3}{16}$	0.197	0.179
$\frac{5}{16}$	0.3125	$\frac{5}{16}$	0.3125	0.302	$\frac{13}{64}$	0.245	0.224
$\frac{3}{8}$	0.3750	$\frac{3}{8}$	0.3750	0.362	$\frac{9}{32}$	0.293	0.270
$\frac{7}{16}$	0.4375	$\frac{7}{16}$	0.4375	0.423	$\frac{21}{64}$	0.341	0.315
$\frac{1}{2}$	0.5000	$\frac{1}{2}$	0.5000	0.484	$\frac{3}{8}$	0.389	0.361
$\frac{9}{16}$	0.5625	$\frac{9}{16}$	0.5625	0.545	$\frac{27}{64}$	0.437	0.407
$\frac{5}{8}$	0.6250	$\frac{5}{8}$	0.6250	0.607	$\frac{19}{32}$	0.485	0.452
$\frac{3}{4}$	0.7500	$\frac{3}{4}$	0.7500	0.729	$\frac{9}{16}$	0.582	0.544
$\frac{7}{8}$	0.8750	$\frac{7}{8}$	0.8750	0.852	$\frac{21}{32}$	0.678	0.635
1	1.0000	1	1.0000	0.974	$\frac{3}{4}$	0.774	0.726
$1\frac{1}{8}$	1.1250	$1\frac{1}{8}$	1.1250	1.097	$\frac{27}{32}$	0.870	0.817
$1\frac{1}{4}$	1.2500	$1\frac{1}{4}$	1.2500	1.219	$\frac{19}{16}$	0.967	0.909
$1\frac{1}{2}$	1.5000	$1\frac{1}{2}$	1.5000	1.464	$1\frac{1}{8}$	1.159	1.091

The width of neck under the heads shall be not over 2 times the pitch of the thread.

The radius of the crown of the head is to be $2\frac{1}{2}$ D.

When the head is not necked it must be beveled not more than 40 deg. under the head.

TABLE 7—FINISHED AND SEMI-FINISHED JAM-NUTS

DIAMETER OF BOLT		WIDTH ACROSS FLATS			Minimum Width Across Corners of Hexagon	THICKNESS		
Nominal	Maximum	Nominal	Maximum	Minimum		Nominal	Maximum	Minimum
$\frac{1}{4}$	0.2500	$\frac{7}{16}$	0.4375	0.428	0.488	$\frac{5}{32}$	0.163	0.150
$\frac{5}{16}$	0.3125	$\frac{9}{16}$	0.5625	0.552	0.628	$\frac{3}{16}$	0.195	0.180
$\frac{3}{8}$	0.3750	$\frac{5}{8}$	0.6250	0.613	0.699	$\frac{1}{4}$	0.227	0.211
$\frac{7}{16}$	0.4375	$\frac{3}{4}$	0.7500	0.737	0.840	$\frac{1}{4}$	0.259	0.241
$\frac{1}{2}$	0.5000	$\frac{13}{16}$	0.8125	0.799	0.911	$\frac{9}{16}$	0.323	0.303
$\frac{9}{16}$	0.5625	$\frac{7}{8}$	0.8750	0.860	0.980	$\frac{11}{32}$	0.355	0.333
$\frac{5}{8}$	0.6250	$\frac{15}{16}$	0.9375	0.922	1.051	$\frac{3}{8}$	0.387	0.363
$\frac{3}{4}$	0.7500	$1\frac{1}{8}$	1.1250	1.108	1.263	$\frac{7}{16}$	0.451	0.424
$\frac{7}{8}$	0.8750	$\frac{13}{16}$	1.3125	1.293	1.474	$\frac{1}{2}$	0.516	0.484
1	1.0000	$1\frac{1}{2}$	1.5000	1.479	1.686	$\frac{9}{16}$	0.580	0.545
$1\frac{1}{8}$	1.1250	$\frac{11}{16}$	1.6875	1.665	1.898	$\frac{5}{8}$	0.644	0.606
$1\frac{1}{4}$	1.2500	$1\frac{3}{4}$	1.8750	1.850	2.109	$\frac{3}{4}$	0.771	0.729
$1\frac{1}{2}$	1.5000	$2\frac{1}{4}$	2.2500	2.222	2.538	$\frac{7}{8}$	0.900	0.850
$1\frac{3}{4}$	1.7500	$2\frac{3}{4}$	2.6250	2.593	2.956	1	1.029	0.971
2	2.0000	3	3.0000	2.964	3.379	$1\frac{1}{8}$	1.158	1.093
$2\frac{1}{4}$	2.2500	$3\frac{3}{8}$	3.3750	3.335	3.802	$1\frac{1}{4}$	1.286	1.214
$2\frac{1}{2}$	2.5000	$3\frac{1}{2}$	3.7500	3.707	4.226	$1\frac{1}{2}$	1.540	1.460
$2\frac{3}{4}$	2.7500	$4\frac{1}{4}$	4.1250	4.078	4.649	$1\frac{3}{4}$	1.669	1.581
3	3.0000	$4\frac{1}{2}$	4.5000	4.449	5.072	$1\frac{3}{4}$	1.798	1.703

The finished top or both top and bottom of jam-nuts shall be flat and chamfered; angle of chamfer with surface 30 deg.; diameter of top, or both top and bottom circles shall be 100 per cent of the nominal width across flats. Tolerance on top flat surface shall be minus 15 per cent. For jam-nuts with a washer-face, the thickness of the washer-face shall be $1/64$ in. The bearing-surface of washer-face shall be 100 per cent of the nominal width across flats. Tolerance on the diameter of the washer-face shall be plus or minus 5 per cent. The thickness of the nut shall be measured from the top of the nut to the bearing-surface.

The axis of the threaded hole shall be at right angles to the washer-face within a tolerance of 2 deg.

and Rivet Proportions for which this Society and the American Society of Mechanical Engineers are sponsors under the procedure of the American Engineering Standards Committee. The Screw Threads Division has since then approved these tables and recommends their adoption by the Society for inclusion in the S.A.E. Standard for Wrench-Head Bolts and Nuts and Wrench Openings commencing on p. C6 of the S.A.E. HANDBOOK.

HIGH NUTS TO BE CHAMFERED

Screw Threads Division Recommends 40-Deg. Finish in Present Standard

When the present S.A.E. Standard for High Nuts, p. C3f of the S.A.E. HANDBOOK, was adopted by the Society, the chamfer was intentionally omitted, as standard practice for thick nuts was expected to be followed. Since then, however, the question of having the standard specific in this regard has been raised and the Screw Threads Division feels that the maximum chamfer should be included to prevent cutting down the sides of the nuts too deeply and defeating their purpose which is to provide a long wrench hold. Some difference in practice as to the amount of chamfer, varying from 30 to 45 deg. with the top face of the nut, seems to exist, and the Division, after considering the suggestions offered, has voted to recommend that high nuts shall be chamfered to the maximum angle of 40 deg. with the top face of the nut without specifying limits. This recommendation will prevent chamfering the nuts too deeply and permit of a shallower chamfer when desired.

MIDSHIP SHAFT MOUNTINGS REVISED

Subdivision on Three-Joint Propeller-Shafts Approves Changes in Previous Report

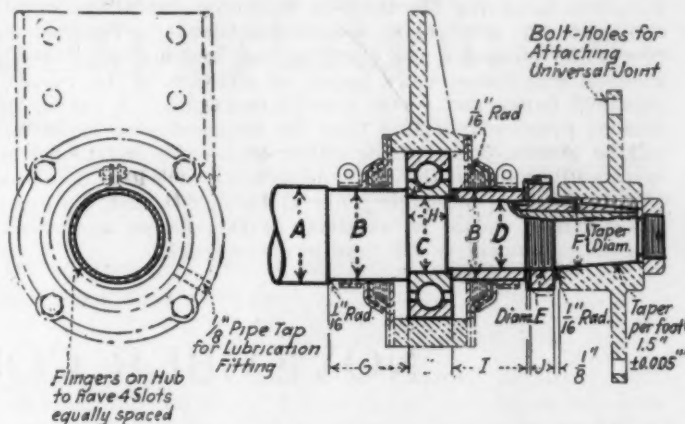
Further revision of the proposed specification for propeller-shaft midship mountings was approved at a meeting of the Subdivision on Three-Joint Propeller-Shafts, held in Boston on Nov. 17, after consideration was given to numerous comments and suggestions received with regard to the previous report that was printed on p. 450 of the November, 1926, issue of THE JOURNAL. While the proposed S. A. E. Recommended Practice shows the bearing housing, this is not a part of the specification and is shown as a suggested design only. Some criticism of the proposal was made on the basis that it does not permit the use of any but the self-aligning type of bearing, but this was met with statements of other bearing manufacturers that the non-self-aligning types of bearing are used as well, especially in the case of bearings with a little looseness in the raceways. The question regarding heavy-duty installations was also raised, but the Subdivision feels that the recommendation will meet all usual practice, and that, as particularly heavy installations should be considered special, the shaft dimensions for heavier bearings should be agreed upon between the manufacturer and the purchaser.

The dimensions of C, as shown in the accompanying table, possibly will be revised inasmuch as these figures have been questioned by the bearing companies, and their recommendations will be sought before the final specifications are submitted to the Standards Committee.

The accompanying illustration and table show the revised design and dimensions.

THREE-JOINT PROPELLER-SHAFT MIDSHIP MOUNTING

The type of housing shown is recommended as a satisfactory design, but is not a part of the standard. No slip-joint in the forward section of the shaft is required, as clearance is provided in the housing for the bearing and shaft to slide longitudinally. Where a slip-joint is used, the housing should be designed according to requirements. The shafts and bearings recommended are considered adequate for all usual installations. Where heavier duty may require larger bearings, the shaft dimensions should be determined by the manufacturer and the purchaser.



PROPOSED S.A.E. STANDARD DIMENSIONS FOR THREE-JOINT PROPELLER-SHAFT MIDSHIP MOUNTING

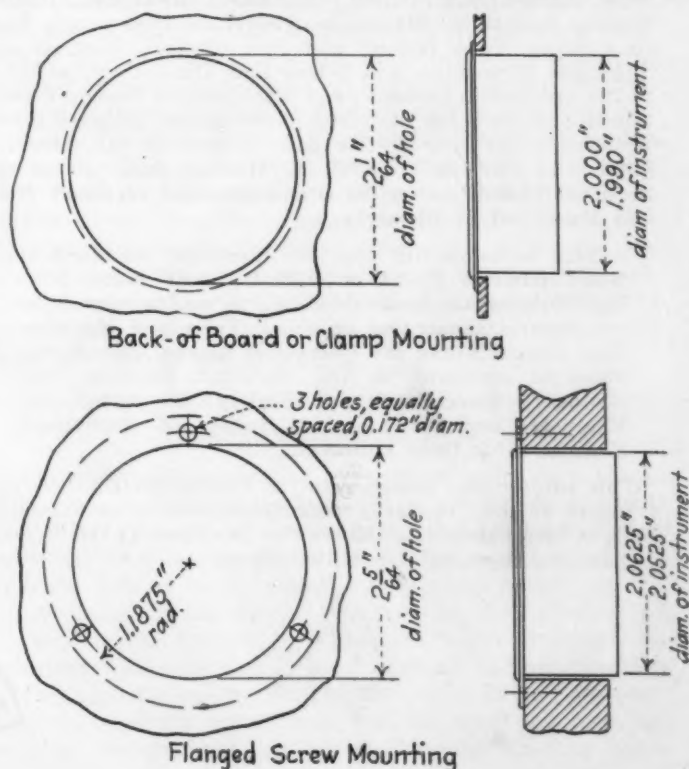
Tube Diameter,	2	2	2 1/4	2 1/2	3
A, in.					
B, + 0.005, — 0 in.	1.687	1.875	2.125	2.375	2.562
C, + 0.001, — 0 in.	1.377	1.574	1.771	1.968	2.165
D, + 0, — 0.003 in.	1.374	1.499	1.624	1.874	2.124
E	1 1/8-18	1 1/2-18	1 3/4-16	1 3/4-16	2 1/4-16
S.A.E. Taper Shaft					
End, F	1 1/4	1 3/4	1 3/4	1 3/4	2
G, in.	1 1/8	1 3/4	1 3/4	2	2 1/4
H, in.	1 1/8	1 3/4	1 3/4	1	1 1/4
I, in.	1 1/8	1 1/4	1 1/4	1 1/4	2 1/4
J, in.	1 1/8	1 1/4	1 1/4	1 1/4	1 1/4
Bearing No.	307	308	309	310	311

Note.—The oil-retainer rings should be adjusted for minimum clearance after the housing and shaft are assembled in the chassis.

INSTRUMENT MOUNTINGS REVISED

Adoption of 2-In. Size Recommended by Electrical Equipment Division

The Electrical Equipment Division has recommended that the present S.A.E. Standard for Instrument Mountings shown on p. B12 of the S.A.E. HANDBOOK, be extended to



include a mounting for the 2-in. diameter clamp-type of instrument on automobile instrument-boards. The report covers the mounting for electrical instruments and for oil, gasoline and temperature gages, in addition to the present standard flange and screw type of mounting. A survey of present practice indicated that the proposed new mounting will be generally acceptable either where the instrument is mounted directly on the instrument-board or where it is one of a group on a sub-panel. The Division felt that the present standard should be retained as this flange and screw type of instrument is still used in motor-trucks.

The revised report as recommended by the Electrical Equipment Division is shown in the accompanying illustration and will be acted on at the meeting of the S.A.E. Standards Committee at the Annual Meeting in Detroit in January.

As a result of discussion at the meeting, work will be continued toward standardizing the size of the terminal studs and the connection on the back of oil, gasoline and temperature gages, probably incorporating the present S.A.E. Recommended Practice for Pressure-Gage Connections shown on p. C45a of the S.A.E. HANDBOOK.

NOVEMBER COUNCIL MEETING

A MEETING of the Council was held at New York City on Nov. 9. Those present were President Little, First Vice-President Hunt, Second Vice-President Guernsey, Councilors Winchester and Chandler, Treasurer Whittelsey, Chairman Scaife of the Constitution Committee, and C. B. Veal, nominee for Councilor for next year. Forty-two applications for individual membership which had been acted on by letter-ballot of the Council were reported and in addition 50 applications were submitted. The resignations of 50 members were accepted. Two reinstatements to membership were made; also 18 transfers in grade of membership. Three hundred and thirty-two members were dropped for non-payment of dues payable Sept. 30, 1925.

In the period from Jan. 1 to Nov. 6, 1926, 760 applications for membership had been received, as compared with 801 applications received during the same months of 1925, and 632 in 1924. On Nov. 6 the rolls of the Society contained 6052 names, including Affiliate Member Representatives, as compared with 5277 on Nov. 7, 1925. From Jan. 1 to Nov. 6, 698 applicants who had been elected qualified as members.

John Younger was appointed as a member of the Production Advisory Committee.

STANDARDS COMMITTEE MATTERS

The following subjects were assigned to the Divisions of the Standards Committee as indicated: Engine-Starter Mountings, Fuel and Oil-Pipe Dimensions, Fuel-System Controls, Hand-Starter Drives, Instrument Mountings, Radial-Engine Mountings, Streamline Steel-Tube Dimensions, Tail-Skid Shoes, Tank Outlets and End Fittings, Vertical and V-Engine Mountings, and Wheel Hub Dimensions, assigned to the Aeronautic Division; and Machine-Tool Standard Data Sheets and Shop Job Standard Specifications assigned to the Production Division. Under date of Oct. 18, the following letter was received from H. E. Harris, chairman of the Sectional Committee on the Standardization of Small Tools and Machine-Tool Elements.

This is to certify that the proposed standard of Sub-Committee No. 1 on T-Slots, their Bolts, Nuts and Cutters has been submitted to and approved by the Central Committee on Small Tools and Machine-Tool Elements and the Committee hereby submits the proposed standard to the National Machine Tool Builders' Association, the Society of Automotive Engineers and the American Society of Mechanical Engineers for their approval.

This subject was assigned to the Production Division for a report at the Standards Committee meeting in January, 1927, in accordance with the regular procedure of the Society in handling Sectional Committee reports.

AMENDMENTS TO BY-LAWS

Paragraphs B18, B30 and B31 of the By-Laws of the Society were amended to read as follows:

B18—The Finance Committee shall, under the direction of the Council, have supervision of all the financial affairs of the Society. The Committee shall make recommendations to the Council as to investments, and, when called upon by the Council, advise upon financial questions.

B30—The Secretary of the Society shall be the Secretary of the Council. The Secretary shall, under the supervision of the Finance Committee, have charge of the books of account of the Society; shall make and collect all bills against members or others; shall have charge of all bills against the Society and shall keep an account of the same; and present to the Finance Committee for its information, statements of all receipts and all disbursements during each calendar month and a statement of the financial condition of the Society at the end of each calendar month, as shown in the monthly comparative balance-sheet, income and expense comparison and budget comparison.

The Secretary shall see that the books of account are audited quarterly by a competent firm of public accountants and a copy of the auditor's reports furnished to each, the Secretary and the Treasurer of the Society, these reports to be submitted at the Finance Committee and the Council meetings.

All funds received by any person for the Society shall be delivered to the Secretary, who shall immediately enter them in the books of account and deposit such funds as he receives to the credit of the Society in a bank to be designated by the Council.

B31—The Treasurer shall make payments only after bills have been checked against goods received and certified by the Secretary or his deputy, or upon the approval of the Finance Committee, or upon the direction of the Council by resolution. He shall furnish a bond for the faithful performance of his duties in such amount as the Council may require, such bond to be procured from an incorporated guarantee company, at the expense of the Society.

The financial statement for the fiscal year ended Sept. 30, 1926, was submitted. This statement showed a net balance of assets over liabilities of \$174,731.15, this being \$12,370.82 more than the corresponding figure on the same day of 1925. The gross income of the Society for the fiscal year ended Sept. 30, 1926, amounted to \$360,638.15, the operating expense being \$338,523.26. The income for the month of September was \$36,418.27. The operating expense during the same month was \$31,515.78.



Scientific Transportation

By W. P. KELLETT¹

TRANSPORTATION AND SERVICE MEETING PAPER

Illustrated with DRAWINGS

ABSTRACT

IN an expedited store-door freight-service, such as obtains in Great Britain, the railroads assume full responsibility for the complete transportation of merchandise freight from the door of the consignor to the door of the consignee. In the American system, the railroads assume responsibility for its movement from station to station only. To the persistent refusal by the railroads of this Country to meet the demands of the public for expansion of the service to include collection and delivery of merchandise can be traced the growth of motor-truck freight-haulage in competition with the railroads. But each of these transportation mediums possesses its greatest strength where the other displays its greatest weakness; consequently, they present an ideal basis for coordination of service along rational lines.

Store-door collection and delivery service is an integral part of a coordinated system and, as a means of reducing the number of handlings of freight necessary by present methods, the use of the container system is receiving increased attention. Among the salient features that such a system should possess are simplicity, ability to load and unload with the same ease and by the same means as are now employed in loading standard railroad equipment, capacity for transferring the containers quickly and easily from the car to the truck chassis without the use of special equipment, and sturdiness and strength to withstand shocks. A description of such a system is given, special attention being devoted to methods of loading and unloading the containers, the cost of transfer, the manner of operation of containers, their economic range of usefulness, the expansion of terminal facilities, the classes of freight best adapted to shipment by containers, and the principal obstacles to be overcome in the introduction of the container system.

FOR many years past an insistent demand has been made in this Country for an expedited store-door freight-service such as obtains in Great Britain, under which, in the movement of merchandise freight, the railroads assume full responsibility for its complete transportation from the door of the consignor to the door of the consignee, as opposed to the American system, under which the railroads assume responsibility for its movement from station to station only.

In spite of strenuous objections on the part of Chambers of Commerce, Merchants' Associations and other representative bodies to the continuance of this system, the railroads have persisted in their refusal to adopt store-door delivery as an integral part of their transportation service. The direct result has been the birth and subsequent enormous growth of a competitive freight-service by motor-truck, a method of transportation that any intelligent analysis will show to be unsound, uneconomic and entirely unnecessary, but one that will continue to expand until the railroads substitute, for a service that has become obsolete, a system of coordinated rail and highway transportation that is founded on sound economic principles, in other words, a scientific system of

transportation in which store-door delivery will, of necessity, play a vital part.

MOTOR-TRUCK COMPETITION

During the war, when the railroad facilities were strained beyond their utmost capacity to move the enormous tonnage born of the war's insatiable needs, the motor-truck, operating over the highways for long distances beyond the terminal area, was looked upon by many competent railroad men with more or less amusement as a "transportation freak" called into existence by the urgent necessity of the hour that tonnage must move regardless of method or cost.

That, with the close of the war, this new form of transportation would cease to exist was freely predicted. Such favorable opinion as then existed held that the motor-truck might possibly find a permanent place in the more rapid transportation of goods from the rail-head to points within the terminal or the suburban area, but no serious consideration was given to it as a possible competitor of the railroads. The motor-truck as a transportation facility did not die, however, nor has it confined its activities to the movement of freight from the rail-head to points within the terminal area. With the extension of paved highways connecting large centers of population, it has entered into direct competition with the railroads in the transportation of high-class freight, over moderate distances at first, but rapidly increasing until, at present, it is actively competing for this class of traffic on hauls up to and in many cases exceeding 100 miles.

At the same time, any intelligent investigation of railroad versus highway transportation by motor-truck must lead to the inevitable conclusion that, insofar as road-haul cost per ton-mile is a factor in the over-all cost or door-to-door transportation, the motor-truck is not now, nor is it ever likely to become, a successful competitor of the railroads. The motor-truck as a competitor for short-haul business survives, for the reason that, having no expensive terminal facilities to maintain and being able through direct door-to-door service to eliminate the heavy cost of freight-shed handling, it can give the people the type of service they demand, namely, expedited service at freight rates plus a moderate charge for terminal pick-up and delivery.

ADVANTAGES AND DISADVANTAGES OF EACH TRANSPORTATION METHOD

The railroad's element of greatest strength as a transportation medium is its low cost per ton-mile of road-haul; its greatest weakness is in the performance of terminal service, in which it dissipates much of the revenue gained in road-haul. The motor-truck, on the other hand, is abnormally efficient in that element of transportation service in which the railroad shows its greatest weakness and is least efficient in that function of transportation in which the railroad is supreme. The motor-truck must look for its profit in terminal service; the moment it takes to the road for long hauls.

¹ Consulting engineer, Brantford, Ont., Canada.

it begins to lose money, so that the distance over which it can compete successfully with the railroad is determined by the savings effected in the terminal areas and by the extent to which it can afford to squander these savings in a road-haul costing per ton-mile from six to eight times that of its steam rival.

The peculiarities inherent in these two systems of transportation, each possessing the greatest strength where the other displays the greatest weakness, present an ideal basis for coordination of service along rational lines that will inure to the benefit of both systems of transport and to that of the public as well.

THE CONTAINER SYSTEM OF TRANSPORTATION

Much thought of a constructive nature has been given to the problem of coordinating rail and highway transportation facilities and to the problem of a store-door delivery as an integral part of this coordinated service. Opinion has not yet crystallized as to the best means by which this combination can be effected, but an increasing number of those who have given the subject intelligent study believe that the logical solution lies in a properly designed container-system that will materially reduce the number of handlings of freight that are necessary by present methods. This applies to carload freight now handled over team tracks, as well as to less-than-carload freight, express and parcel post.

To be effective, the type of container system adopted must be one that presents no new or added difficulties in the loading of freight. It must be of a type that allows the loading of the container, while in place on the flat car, with the same ease and by the same means that are now employed in the loading of standard railroad equipment. It must, at the same time, be capable of being transferred from the railroad-car to the truck chassis, or vice versa, quickly and easily, without the use of special equipment such as hoists, cranes, derricks, or other types of lifting-apparatus. It should be of sufficiently sturdy construction to withstand the shocks inci-

dent to rail transportation, without being unduly heavy in proportion to its carrying capacity.

These, I think, are some of the salient features that any container system must possess, if it is to become an effective medium through which efficient coordination of rail and highway transportation facilities may be brought about. In the container system shown in the accompanying illustrations an attempt has been made to incorporate in the design features that will enable it to comply with the requirements noted. It is offered for consideration, not as a definite solution, but in the hope that it may at least suggest ways and means by which a coordinated rail and highway transportation system can be evolved which will be capable of transporting freight from the consignor to the consignee with the minimum expenditure of mechanical or manual effort.

DETAILS OF CONSTRUCTION

The container system under consideration includes essentially one or more standard railroad flat-cars provided with trackways for the container wheels. These trackways are composed of light steel channels laid flush with the car deck to a gage corresponding to the gage of the container wheels.

Containers may be provided for any type of service. Fig. 1 shows the merchandise or box-car type for carload freight, subdivided merchandise-containers for less-than-carload freight, the gondola type for commodity freight, and side or end-unloading containers for express or parcel post; but other types of containers for other commodities, such as lumber, live stock, poultry, and the like, will readily suggest themselves. With the exception of the parcel-post and express type, all containers are designed exclusively for end loading and unloading. The parcel-post and express type consists of two containers mounted on a truck frame similar in design to that of the other types of container mentioned. These containers can be side loaded or unloaded directly from the railroad-car to the platform or the station-truck, from

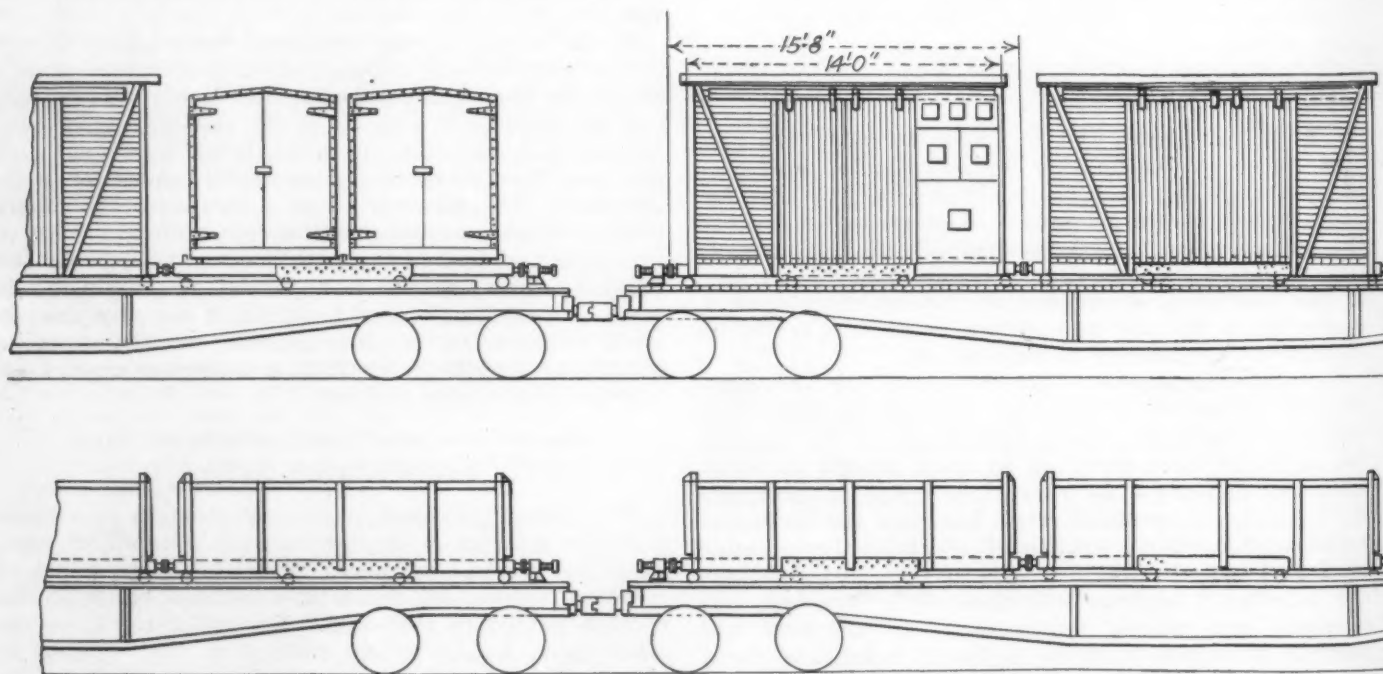


FIG. 1—GENERAL ARRANGEMENT OF THE CONTAINER SYSTEM, SHOWING THE METHODS Containers for Parcel Post Are Designed for Side or End Loading, as Desired. All Other Types Have Been Designed Solely for End of Goods from Car to Car or from Road Vehicle to Platform or Vice Versa. All Trailers Used in Hauling Gondola-Type Containers Platform at the Street End, To

which they may be transferred to the motor-truck chassis; or they may be end loaded or unloaded in pairs in the same manner as other containers.

All containers are provided with four short safety-chains, one at each corner, that are used to couple them together when in place on the railroad-car. They are of the roll-off cantilever type, equipped with four sets of small caster-wheels, which allow their being moved freely in any direction on the loading platform or on the floor of the freight shed or other building. The distance, center to center, between each pair of wheels being greater than the maximum opening between the end-sills of the coupled railroad-cars, no bridging of this opening is necessary to facilitate their movement from car to car, or from platform to car, during the process of loading or unloading, provided always that the opening between the railroad-car and the platform is not greater than the maximum opening between the end-sills of the coupled railroad-cars.

SECURING THE CONTAINERS IN PLACE

To secure the containers in place, cars are equipped with side locking-bars firmly fixed to the car floor, which engage a suitable angle attached to the side sill of the container frame. Adjustable spring-cushioned buffers are provided at each end of the car to limit the longitudinal movement of the containers. These end buffers are designed so as to allow their being lowered flush with the car deck so that the containers can be rolled from car to car or from the car to the loading platform or shed floor or vice versa during the process of loading or unloading.

Containers are equipped with end buffers, as shown, each buffer having a maximum spring-compression of 3 in., so that the maximum spring-cushioned longitudinal movement of the three containers is 19 in., 15 in. of which is provided by the container buffers and 4 in. by

¹See Draft Gear and Its Relation to Railway Economies, by W. H. Miner, Inc., Chicago.

the end car-buffer. That the importance of this feature may be fully appreciated and the effect of uncushioned shocks on railroad revenues may be more clearly understood, I quote the following from a most excellent treatise¹ on this subject:

Ever since the automatic coupler came into general use, it has been customary to couple freight-cars by impact, until now this practice has in a measure become a legal requirement. During the last 30 years operating and switching conditions have so increased in severity that coupling by impact has become a serious factor of railroading. One has only to visit a modern classification yard and trace thence the effect of "coupling by impact" to the repair-shops to understand how extremely expensive is this practice.

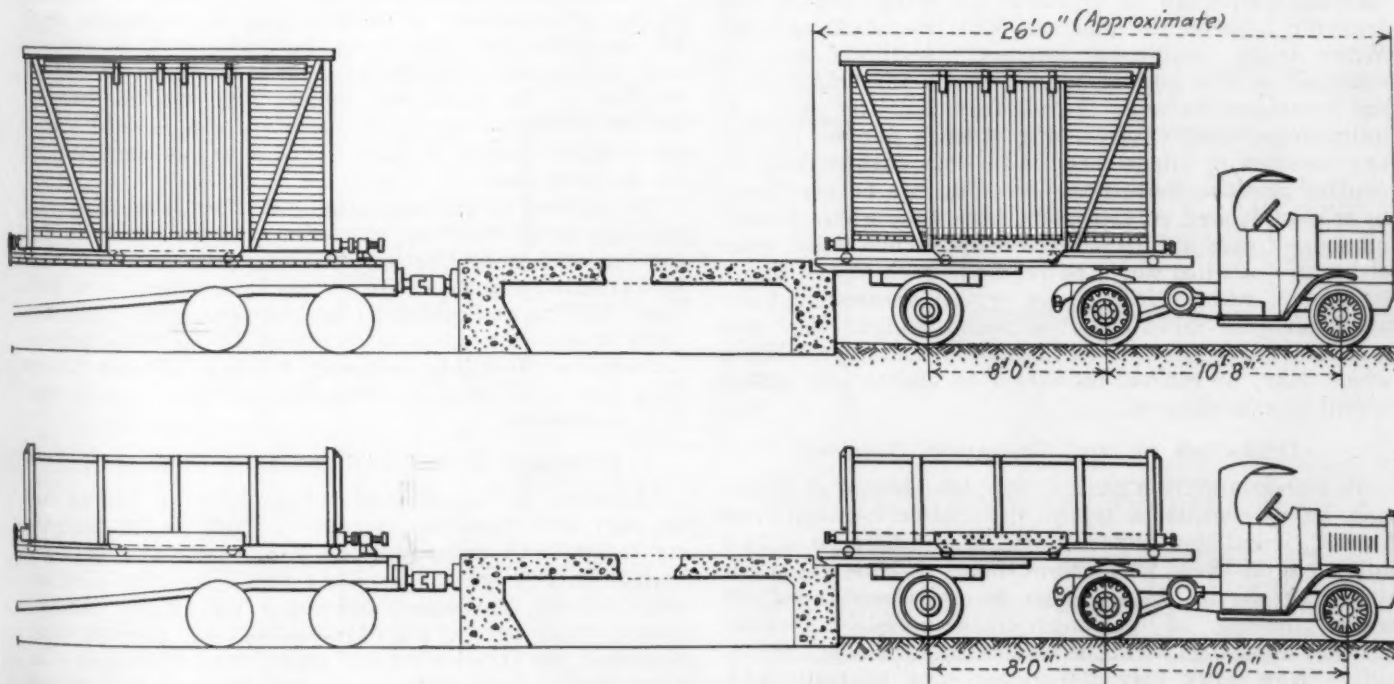
The most tangible evidence of the present cost of automatic coupling is the annual expenditure of approximately \$50 000,000 in settlement of claims for goods damaged during transit, which constitutes a revenue loss of nearly \$100 per min. High-speed switching is an important contributing factor in producing this unnecessary and disastrous result.

It has also been conservatively estimated that rough handling results in losses, due to expensive repairs and to the shortened life of car equipment, amounting to at least \$150,000,000 per year, a financial drain at the rate of nearly \$300 per min. Derailments and wrecks, as well as costly delays, are often caused by the ultimate failure of some part of a car previously strained by a rough-handling shock.

It is obviously essential to consider seriously the fundamentals relating to this question of automatic coupling, because its proper solution will result in enormous savings in capital expenditure, also in maintenance and operating costs.

LOADING AND UNLOADING CONTAINERS

The only operation necessary, prior to unloading, is to slack the adjusting-screws mounted in the end buffers, so that they can be lowered flush with the car floor. This having been done, containers can be transferred



OF LOADING AND UNLOADING AND OF TRANSFERRING MERCHANDISE TO ROAD VEHICLES

Loading and Unloading. The Containers Are Constructed So That No Support Is Necessary between the Cars To Facilitate the Transfer Should Be Equipped with Elevating and Dumping Machinery. At Important Centers, a Power-Winch Should Be Installed under the Facilitate the Loading and Unloading

from the railroad-cars to the loading platform or freight shed. As many containers as the length of the platform or shed floor will accommodate can be unloaded at one operation by coupling the containers on each car to those on the succeeding car in as great a number as it is desired to unload, the train of containers being then pulled off by power-winch or tractor.

The loading operation can be performed by pushing containers on the cars with a suitable tractor, or by pulling them on singly or in trains by a cable operated through a snatch-block attached to the head end of the train of cars to be loaded. Transferring the containers from the shed floor or the loading platform to the truck chassis may be performed manually, or by the truck winch. When operated over suitable floors, it has been demonstrated that containers of this type, loaded up to 5 tons, net weight, can be moved freely in any direction by one man.

COST OF TRANSFER

Assuming that the freight house or platform is served by two inbound and two outbound tracks and is of sufficient length to allow the unloading of 5 cars at one operation, the unloading of 10 cars, 5 on each track, that is, a total of 30 containers, should be accomplished by a crew of 8 men, in less than 15 min. The time required by this same crew to load an equal number of containers should not exceed 30 min.

The total labor-cost of transferring containers from the cars, over the platform or shed floor to the truck or trailer chassis, should not exceed \$0.09 each, while the reverse or loading operation should not exceed \$0.13, an average cost per container, for loading or unloading, of \$0.11. On an average of 4 tons per container, the cost is approximately \$0.0275 per ton. The above refers to the direct-labor cost only, for the specific operation named, and must not be taken as representing the total cost, in which would be included clerical labor, supervision and other overhead expenses.

Fig. 1 shows a simple platform for loading or unloading, which can be arranged for either end or side transfer between the platform and the truck, or both. When traffic conditions warrant, platforms may be equipped with a power-operated winch for transferring the containers between the platform and the cars. At unimportant points, where only a small number of cars are received or dispatched daily, this feature may be omitted and the loading or unloading can be performed by manual labor. At important terminals, where a large number of cars are received and dispatched daily, more elaborate facilities would be required, such as are shown in Fig. 2, which illustrates a typical arrangement for a combination inbound-and-outbound freight shed and terminal warehouse for the storage of container freight, which may, of course, be varied to almost any extent to suit local conditions.

OPERATION OF THE CONTAINER SYSTEM

To understand, in a general way, the method of operation, let us consider a typical installation between New York City and New Haven, Conn., a rail distance of 72.3 miles, by the New York, New Haven & Hartford Railroad, the service being given by merchandise-freight trains moving at passenger-train speed. Assume, further, that stops would be made at the following points only: New York City, 0.0 miles; New Rochelle, 16.6 miles; Stamford, 33.1 miles; South Norwalk, 41.0 miles; Bridgeport, 55.6 miles; and New Haven, 72.3 miles.

The container operation covering less-than-carload

freight would be about as follows: Freight originating at New York City and consigned to way points between New Rochelle and Stamford would be loaded on the New Rochelle car in the subdivided type of merchandise containers carrying freight consigned to way points between these centers. Small consignments would be placed in the compartments shown, each container being equipped with 12 of these compartments of varying sizes, 6 on each side.

The containers would be removed from the cars at New Rochelle and would be hauled over the highway to Stamford by tractor, making deliveries to way points en route. Each tractor would haul one loaded and one empty container. Empty containers would be loaded en route with east-bound carload or less-than-carload freight, which, on arrival at Stamford, would be sorted as to destination and consolidated with freight originating at Stamford and consigned to points east of South Norwalk. Any freight originating at way points between New Rochelle and Stamford and consigned to way-points between Stamford and South Norwalk would be transferred to the east-bound containers operating out of South Norwalk, that is, a transfer would be made or the trailer loaded to capacity, whichever method involved the less amount of labor.

The same arrangement would apply to all points between New York City and New Haven, or any other points to which the system was operated. In the typical example noted, freight originating at New York City and consigned to way points between New York City and New Rochelle would move entirely by truck. The same would apply, of course, to freight originating at way points between New York City and New Rochelle and consigned to way points between New Rochelle and Stamford.

In other words, a complete store-door transportation service by two parallel systems of coordinated transportation would be instituted using the railroad for the long haul and the highway for local pick-up and delivery service.

Express and parcel-post shipments would be handled in the same manner as less-than-carload shipments, with the exception that they would be transported in express and parcel-post containers. Carload freight would be handled in the same way as less-than-carload freight, but its movement would be materially simplified because the container would be fully loaded with one consignment to one consignee.

No system of transportation, whether it be rail and highway or all highway, can eliminate the necessity for sorting and consolidating miscellaneous less-than-carload freight; and the above system is no exception to this rule. Sorting and consolidating to make up full container loads to one destination or to way points between principal centers will still be necessary but to no greater extent than that performed by competing highway transportation companies.

ECONOMIC RANGE OF CONTAINER OPERATION

Statistics of the railroads of the United States for the year 1924 show the average haul per loaded freight-car to be 304.4 miles and the percentage of empty-to-loaded-car mileage, to be 53.6; therefore, the average miles per car trip loaded and empty was 467.6. As the average miles per car per day was 26.8, the average time consumed per trip loaded and empty was 17.4 days. In other words, during the year, each car was loaded and unloaded approximately 21 times. Keeping in mind the major economies that can be effected by the use of container equipment in the cost of terminal operation, it

seems logical that, for such traffic as is within its scope, the container car should be adopted as standard equipment.

EXPANSION OF TERMINAL FACILITIES

In 1910, the railroad track-mileage in the United States was 240,438.84; by 1924, it had reached a total of 250,155.85, an increase of 9,717.01 miles; but during this same period yards and sidings increased 26,671.51 miles, or from 85,581.93 miles in 1910 to 112,253.44 in 1924. This enormous increase in yard and terminal facilities was necessary to enable the railroads to handle the vast increase in the volume of tonnage that took place during that period. Further expansion on any extensive scale, however, especially in metropolitan centers, would seem to be impossible, as the value of land in these areas has reached a point that makes its use for this purpose almost prohibitive.

Under a system of transportation by containers, extended to include carload as well as less-than-carload merchandise-freight and certain commodities, such as sand, broken stone, brick, and the like, our present terminal facilities would be more than adequate to meet the transportation needs for many years to come. Under this system, each railroad would have, as an extension to its terminal mileage, the entire highway mileage of the community that it serves, on terms of absolute equality with its competitors, either rail or highway. Railroads serving large cities that, through lack of funds or otherwise, have been compelled to locate their freight terminals at outlying points, would be under no serious handicap as against their more centrally located rivals. They would be subjected only to a longer truck-haul to serve the terminal area, the cost of which would in all probability be more than offset by the smaller investment in terminal facilities.

The class of freight for which container operation is

adapted covers practically all freight that must be teamed or trucked to or from the railroad and that can be loaded into containers of the maximum size permitted by highway regulations. In the short-haul transportation of such construction materials as sand, gravel, broken stone, brick, reinforcing steel, and the like, the container system will produce material savings. For instance, the transfer of brick from railroad-cars to trucks or other means of conveyance in New York City is costing, exclusive of the cost of the waiting time of the truck or team, not less than \$1.35 per thousand. Shipment by container cars would eliminate all but a mere fraction of this expense.

OBSTACLES TO BE OVERCOME

The development of mechanical or other equipment necessary or the efficient coordination of our rail and highway transportation facilities, important though it may be, will not of itself solve our transportation problem. The real obstacles to the institution of such a service are those which lie outside the fields of engineering, but which, nevertheless, are real and tangible. They are obstacles that must be faced squarely and dealt with intelligently before "scientific transportation" can be more than an engineer's dream. Let us, therefore, dig some of these Ethiopians out of the woodpile and stand them up in the order of their relative importance, so that we may see just how formidable they really are.

In the first place, we can take for granted that the only type of service which will eliminate motor-truck competition in the field of short-haul transportation, is store-door freight-service operated on a time-schedule equal or superior to that given by the motor-truck. This being true, any railroad that decides to institute such a service must be prepared to accept all, or practically all, the traffic now handled by the express companies within the area to be served by this fast-freight service, as no

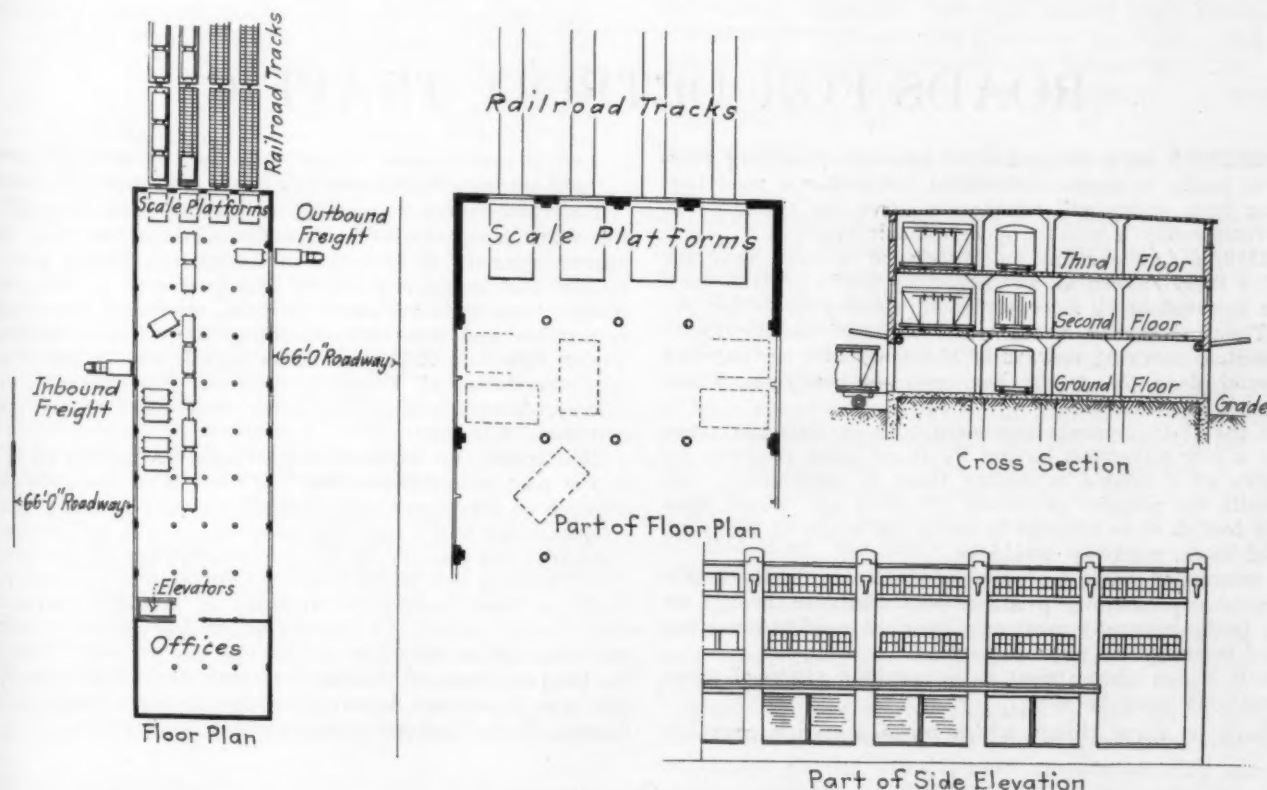


FIG. 2—TYPICAL ARRANGEMENT OF COMBINATION INBOUND AND OUTBOUND FREIGHT SHED AND TERMINAL WAREHOUSE FOR THE STORAGE OF CONTAINER FREIGHT

This Arrangement Can, of Course, Be Varied to Almost Any Extent To Meet Local Conditions

shipper in his right mind will consent to pay express rates for a service that he can obtain at freight rates plus a reasonable charge for collection and delivery.

RESULTS OF INSTALLING STORE-DOOR FREIGHT-SERVICE

The immediate result of such a service would be to flood the railroad instituting it with a multitude of small shipments, with which, by training or experience, its personnel is entirely unfitted to deal. On the other hand, the express companies have been dealing with this class of traffic for many years, and the fact that little or no public complaint against the service exists is proof that they are the proper medium through which this class of traffic should be handled.

The real solution of this difficulty would seem to lie, not in crippling the express companies, but in the railroads' making an arrangement with them that would allow them to extend their field of operation to include the transportation of all less-than-carload freight shipments weighing 150 lb. or less. This class of less-than-carload freight might, for convenience sake, be designated as "class-B express." It would be transported on the same trains as other less-than-carload freight but would be loaded in express-company containers. The only difference, insofar as the public would be concerned, would be that collection and delivery would be made by the express companies instead of by the railroads. Such an arrangement would, of course, be subject to the approval of the Interstate Commerce Commission and to authority being given to the railroads to refuse, for transportation within the area covered by its expedited freight-service, consignments weighing less than 151 lb.

From the point of view of the railroads, an arrangement of this kind should prove entirely acceptable, as it would materially increase the average weight per shipment of the remaining less-than-carload tonnage, reduce the amount of labor involved in sorting, classifying and

consolidating consignments and, by reducing the average number of consignments per container, would reduce the cost and simplify the collection and delivery of less-than-carload freight.

CONSIGNEE'S RIGHT OF NOTICE OF ARRIVAL OF SHIPMENT

The next obstacle to be overcome is the consignee's right of notice of the arrival of the shipment, and his free time of 48 hr. in which to unload carload freight. Obviously, no expedited service is possible so long as these rules remain in force, but store-door delivery of the merchandise freight and commodities noted cannot come as a wholesale innovation; the introduction of this service must be gradual. Store-door delivery should, at first, be optional with the consignee, upon whom would rest the obligation to see that container loading was requested by the consignor. Container service should be given subject only to the consignee's foregoing the right of notice of the arrival of the car or of the shipment and his agreeing to accept freight when delivered. What the great majority of shippers desire is expedited store-door freight-service, but, until they are certain that satisfactory service will be given, they are not likely to consent to the nullification of any rights that they now possess; but once they have confidence in the service, reforms will be comparatively easy.

These seem to be the most serious obstacles that stand in the way of an expedited store-door freight-service through intelligent coordination of rail and highway transportation facilities. No doubt there are many others, but, if these major difficulties can be overcome, we can take for granted that those of a minor nature will not be found impossible of solution. Motor-truck freight-haulage in competition with railroads is wasteful, unsound in principle and unnecessary, but it will continue and will expand until the railroads offer a better service for less money.

ROADS FOR DETROIT TRAFFIC

WHETHER an existing road is adequately serving present traffic is easily determined. Whether a road that is being built today will adequately serve the traffic of 10 years from today is a much more difficult problem.

In 1913, a traffic count on Woodward Avenue near the Six Mile Road showed an average daily traffic of 2160 vehicles as determined by a weekly count continuing 24 hr. per day. Today this road, now 2 miles inside of the city limits of Detroit, is carrying upward of 15,000 vehicles per day and on special days the traffic has been as heavy as 30,000 vehicles of all classes.

That the 18-ft. concrete pavement built in 1909 has given way to a city pavement having 27 ft. of clear roadway on each side of a double street-car track is interesting. To have built the present pavement 16 years ago would have been as foolish as to attempt to carry the traffic of today on that old 18-ft. roadway would be.

The amount of traffic a given road must carry is the traffic that the local community produces plus whatever through or foreign traffic naturally must pass over the road to serve the needs of communities more distant.

Francis Bacon must almost have caught a vision of present conditions when he said:

There be three things which make a nation great

and prosperous, a fertile soil, busy workshops and easy conveyance for man and goods from place to place.

The Government in an attempt to distribute Federal Aid for roads in an equitable manner and also one that would approximate the traffic needs of the various States, provided by law that the money should be apportioned to the several States, "one-third according to area, one-third according to population and one-third according to post-road mileage." Under this rule Michigan ranks eighth among the States, only the States of Texas, New York, Pennsylvania, Ohio, Illinois, Missouri, and California receiving more Federal Aid than Michigan.

That traffic can increase in the future as rapidly as it has in the past seems impossible but, even if it does, the main arteries of travel entering Detroit, supplemented by nearly a dozen other and lesser important roads that will be extensions into the country of the super-highways of the Detroit City Planning and Rapid Transit Commission, will carry the traffic at least during the lifetime of the first pavements laid, say 20 years. To lay our plans too definitely beyond this may not be wise for no one can predict with certainty the kind or types of vehicle, including interurban cars, that will have to operate on our highways 20 years hence.—F. F. Rogers, State Highway Commissioner of Michigan.



The Importance of Tire Service in Motorcoach and Truck Operation

By J. M. LINFORTH¹

TRANSPORTATION AND SERVICE MEETING PAPER

Illustrated with CHARTS

ABSTRACT

THOROUGH study and analysis of the details that influence the proper operation of motor-vehicles are important, if the efficiency of the equipment is to be increased and the cost of operation reduced to the minimum. Pneumatic tires have played an important part in the success of the automotive vehicle, for they provide the cushion for the vehicle and the load and allow the movement of passengers and freight at a high speed over all kinds of highway. In the development of the larger motorcoach and truck tires, many factors have been presented that were not experienced in the development of the smaller sizes for passenger-cars. Many tire problems are common to both the motor-truck and the coach, but, in the present discussion, special attention has been devoted to those of the motor-coach. Fleet-owners are becoming more and more sensitive to involuntary road delays because of tire failures; the tires must therefore be studied with the idea of reducing to the absolute minimum the road delays that can be attributed to pneumatic-tire design, manufacture and use.

The studies described in the present paper have been made with a view to improving fleet operation and have been undertaken through a desire to prevent involuntary stops or interruptions to motorcoach schedules that are traceable directly to tire and tube performance.

A series of charts is reproduced which gives the results of data collected on such subjects as the time at which interruptions are most likely to occur, the causes of various delays, the general causes of tire change over a 5-month period, the causes of tire change attributable to various operations, the causes of flat tires, the points at which flat tires occur, that is, which wheel and which type of vehicle are mostly responsible for them, the influence of brake-drum heat on tire performance, and the rise of air pressure in the tire due to excessive brake-drum temperature. Other charts depict the improved service obtainable when attention is paid to all the factors influencing tire performance and show the four sizes of balloon tire that are most likely to come into general use.

Among the advantages that are said to be obtainable through the use of balloon tires are greater comfort for passengers, lower mechanical up-keep, greater ground contact, an increase in the average speed without an increase in the maximum speed of the vehicle, and the probable increase in tire mileage.

HIGHWAY transportation in recent years has assumed a position in the economic structure of business that is second only to the commodities or the service provided for the public welfare. It is becoming increasingly important therefore, that details influencing the proper operation of motor-vehicles should be thoroughly studied and analyzed for the purpose of increasing the efficiency of the equipment and, at the same time, of decreasing to the minimum the operating cost.

Modern transportation over highways by motorcoaches

and motor-trucks is undergoing many drastic changes aside from the mechanical developments that, during the last few years, have contributed so much toward the success of the new industry. It is indeed an encouraging situation to find that practically every branch of activity connected with the movement of passengers and freight by motor-vehicles is alive to the responsibilities of its particular task and is enthusiastic concerning the possibilities for the expansion and the betterment of existing conditions. Good roads have contributed largely to the establishment of this industry. Broad continuous bands of concrete now connect practically every point of importance and, as a result, distances once considered prohibitive are covered with ease and comfort. The automotive engineer and the road-builder have performed their tasks in a highly commendable manner, certainly in keeping with the spirit of the industry they represent.

It is my purpose to present the point of view and some of the problems of the rubber-tire manufacturer, to acquaint you with a few of the obstacles he has successfully overcome in the past and to assure you of the serious way in which he is going about the solution of present-day difficulties and of his sincere desire to keep pace with the rapid developments of the transportation industry. Many of my remarks will have reference to motorcoach operation, but the limited time allowed for a discussion such as this prevents me from going into details intimately associated with the motor-truck. Nevertheless, many tire problems are common to both the coach and the truck.

INFLUENCE OF PNEUMATIC TIRES ON THE DEVELOPMENT OF AUTOMOBILES

That pneumatic tires were a highly important contribution to the success of the automotive vehicle goes without question. Indeed, it is difficult to visualize just where the automotive industry would find itself today if solid-rubber tires were still the universal equipment. Pneumatic tires provide the cushion for the vehicle and the load and allow the movement of passengers and freight at high speed over all types of highway. Their development has not been without serious problems for either the manufacturers or the users. To develop a product capable of delivering 20,000 miles of service with proper attention to the service in such exacting work as that demanded by the truck and the motorcoach has really been an accomplishment worthy of note, especially when we reflect that smaller tires for ordinary passenger-car service delivered only 3500 miles 12 years ago and that only in recent years have they reached the point where mileage in the neighborhood of 15,000 is common.

Many factors were presented in the development of the larger motorcoach and truck tires that were not experienced in the development of the smaller sizes for passenger-cars. In the case of the latter, the rated loads were fairly well known and were seldom greatly exceeded. The owner, usually actuated by pride of posses-

¹ Manager of highway transportation department, Goodyear Tire & Rubber Co., Akron, Ohio.

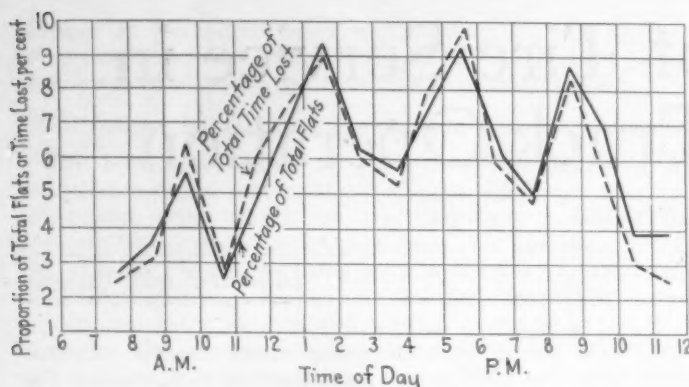


FIG. 1—PERCENTAGES OF THE TOTAL NUMBER OF FLATS AND OF THE TOTAL TIME LOST AT DIFFERENT PERIODS OF THE DAY
Four Distinct Peaks Are Evident. Five and One-Half Per Cent of the Flats Occur between 7:30 and 9:30 A. M. during Which the Traffic Is Heavy on Account of the People Seeking Their Places of Employment; 9.5 Per Cent during the Second, between 12:30 and 2:00 P. M., Caused by Lunch-Hour and Matinee Traffic; a Similar Volume during the Third, between 5:00 and 6:00 P. M., Due to Homeward-Bound Traffic; and 8.75 Per Cent during the Fourth, between 8:00 and 9:00 P. M., Which Can Be Traced to Theater Crowds. After This the Traffic Falls Off as the Motorcoaches Return to the Garage

sion, or by a desire for economy, exercised due care in operating the car. He was apt to judge the performance of the tires by the length of time they remained on the car and not entirely by the actual mileage delivered. On the other hand, motorcoach and truck tires operate very differently. Loads vary greatly, depending on the capacity of the vehicle and on whether standees are allowed. Baggage racks and special equipment also add to the weight. The roads and grades over which the vehicle travels require the frequent use of brakes, which con-

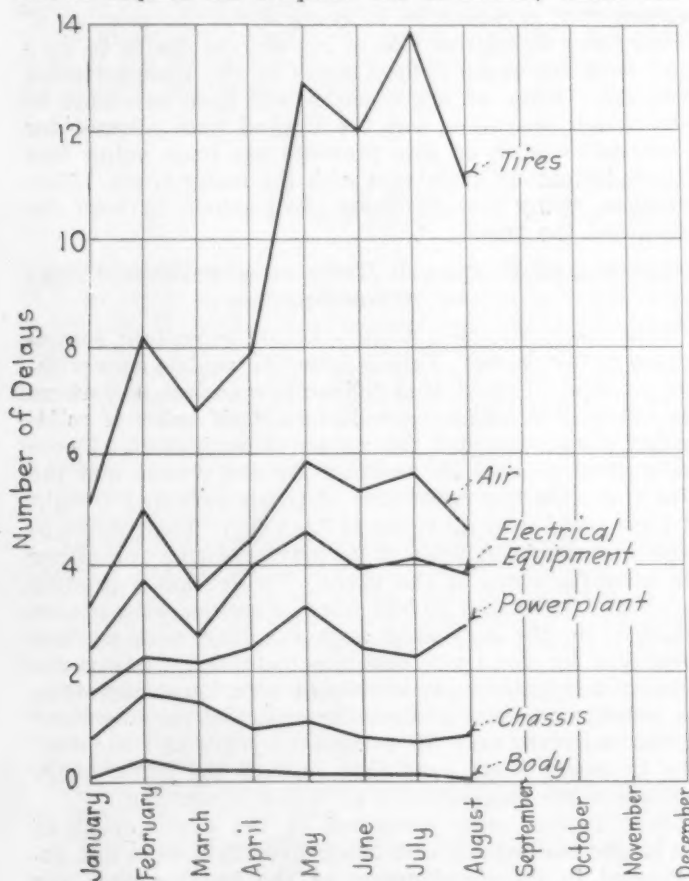


FIG. 2—MOTORCOACH DELAYS ATTRIBUTABLE TO VARIOUS CAUSES DURING A 6-MONTH PERIOD
Tire Troubles Exceed All the Others and Are Particularly Numerous during the Hot Summer Months

tribute heat, either in the tire itself, or as a result of high temperatures of the brake-drum. Proper personnel is another important factor influencing tire performance, for it is the usual thing to find drivers who have no idea of proper tire use and apparently care little about the efficiency and the economy of tire service. Mileage records or performance data are usually kept in most fleet operations, and it is definitely known which tires do or do not give satisfaction.

REDUCTION OF INVOLUNTARY ROAD-DELAYS

Fleet-owners are becoming more and more sensitive to involuntary road-delays. Factors influencing such delays are rapidly assuming a greater importance in the

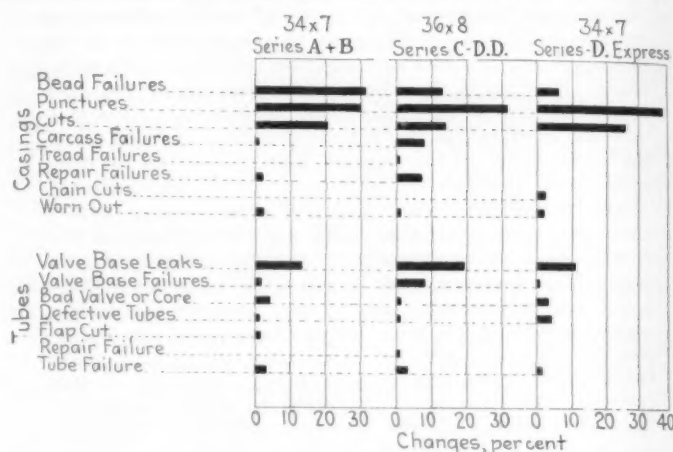


FIG. 3—CAUSES OF ROAD DELAYS BECAUSE OF TIRES OVER A 5-MONTH PERIOD

This Study Is of Value inasmuch as It Shows Exactly What Is Happening to the Tires and the Tubes and Which Factors Are Outstanding. Bead Failures Are an Inherent Weakness. On the Other Hand, Operating Conditions May Create Extreme Brake-Drum Temperatures That Result in Premature Destruction of the Tires, Due to the Influence of Heat

problem of the mass transportation of passengers or freight. Tire performance, no less than mechanical efficiency, is naturally a pertinent part of a well-operated and successful transportation agency. Tires must stand up and contribute their part toward the continuity of service and the maintenance of schedules. They must be studied with the idea of reducing to the absolute minimum road delays that can be attributed to pneumatic-tire design, manufacture and use.

In this paper, an endeavor will be made to describe a few of the interesting results of various studies of tires that have been made with a view to improving fleet operation. In making these studies we have been actuated by a desire to prevent involuntary stops or interruptions to motorcoach schedules that are traceable directly to tire and tube performance. Naturally, an ounce of prevention, in cases in which the movement of passengers on a regular schedule is concerned, is worth many pounds of cure but, unless a study has been made of the causes of involuntary road-delays, it will be difficult to suggest means for their prevention.

In many instances, the number of road delays traceable to the tires and tubes follows very closely the peak-hours of motorcoach operation, that is, they occur at hours when the traffic is the heaviest and when interruptions to the schedules are most costly and inconvenient.

PEAKS IN THE OPERATING SCHEDULE

Fig. 1 is typical of a number of operations in large cities. Attention is directed to the four distinct peaks, the first of which occurs between the hours of 7:30 and

IMPORTANCE OF TIRE SERVICE

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9:30 a.m., during which the traffic is heavy, as the people are seeking their places of employment; the second, between 12:30 and 2:00 p.m., due to the lunch-hour and matinee traffic; the third, between 5:00 and 6:00 p.m., due to the homeward-bound traffic; and the fourth, between 8:00 and 9:00 p.m., which can be traced to theater crowds, after which traffic falls off and the motorcoaches return to the garage.

It is interesting to note that the first peak accounts for 5.50 per cent of the flats; the noon peak, 9.50 per cent; the late afternoon peak, a similar volume; and the late evening peak, 8.75 per cent. The time lost to motorcoaches or schedules, as indicated by the dotted line, shows a similar condition, this curve being based on the time reported by the mechanical department over a 4-month period.

Fleet operators are paying more and more attention to the subject of road delays, as is indicated by Fig. 2, which shows the delays attributable to various causes, the data for which were collected over a 6-month period. The numerous delays caused by tire and tube trouble, in comparison with those due to other factors, such as the body, chassis, powerplant, and the like, are apparent. This particular operator naturally has a tire problem on his hands; and it is essential that he should exert every effort to determine the cause of all road delays and take steps to prevent them. Experience has shown that more trouble is to be expected from tires during the hot summer months. This is indicated on the chart by the

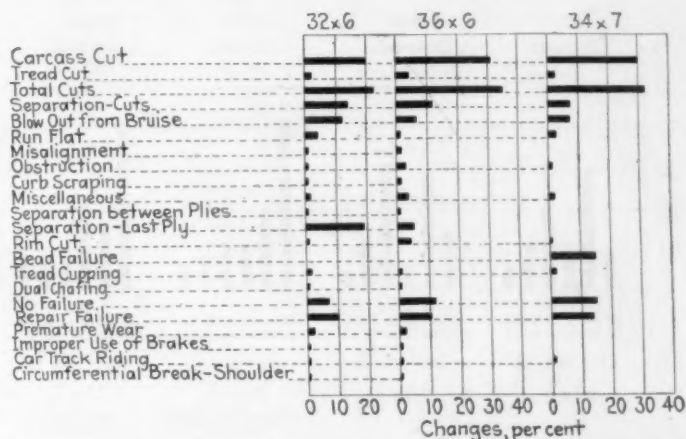


FIG. 5—MORE DETAILED ANALYSIS OF THE CAUSES OF TIRE CHANGE OVER A 4-MONTH PERIOD ENDED APRIL 30, 1926

Such items as "No Failure" provide interest to the operator, for the reason that, in this instance, a considerable number of tires showed no cause for going flat. Investigation disclosed a practice on the part of the drivers of reporting a tire failure at the end of the line so that they might enjoy a rest or layover

found in Fig. 3, which presents the cause of tire changes over a 5-month period and is of value inasmuch as it shows exactly what is happening to the tires and tubes and what factors are outstanding. Bead failures may be an inherent weakness in the design of the tire. On

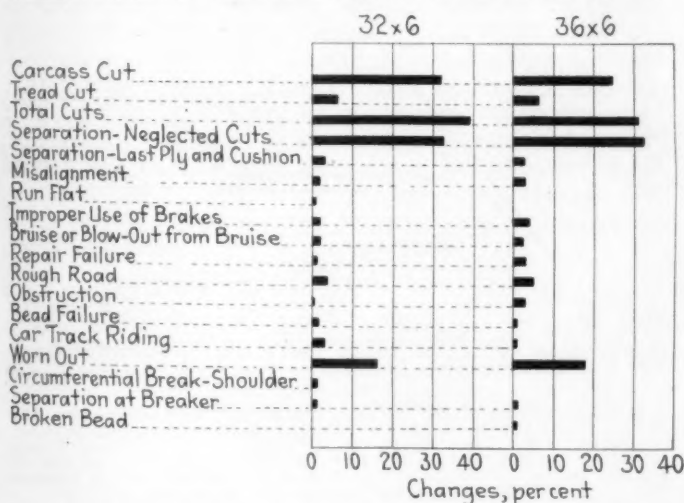


FIG. 4—ANOTHER ANALYSIS OF THE CAUSES OF TIRE CHANGE DURING A 7-MONTH PERIOD

Various Operations Show Different Causes. Cuts Predominate and Were Traceable to the Habit of Motorcoach Drivers of Seeking the Car Rails and of Running in Them. Because They Provide More Comfortable Riding than Uneven Cobblestone Pavements

increase in the number of tire delays beginning with the month of May.

EFFECT OF INTERRUPTIONS OF SCHEDULES

Interruptions of schedules are costly, not only in the actual expense involved, but also in the effect on the good will of the public and the loss of earning power of the vehicle when it is delayed or tied up. We submit that it is considerably more desirable to take precautions in the garage, when the motorcoach is laid up for storage or repairs, than to allow road delays, if they can be averted. The fact that most delays occur at peak-hours, as was shown in Fig. 1, makes it doubly imperative to seek preventive measures. To determine accurately what causes road delays because of the tires, a number of studies were made, some of the details of which will be

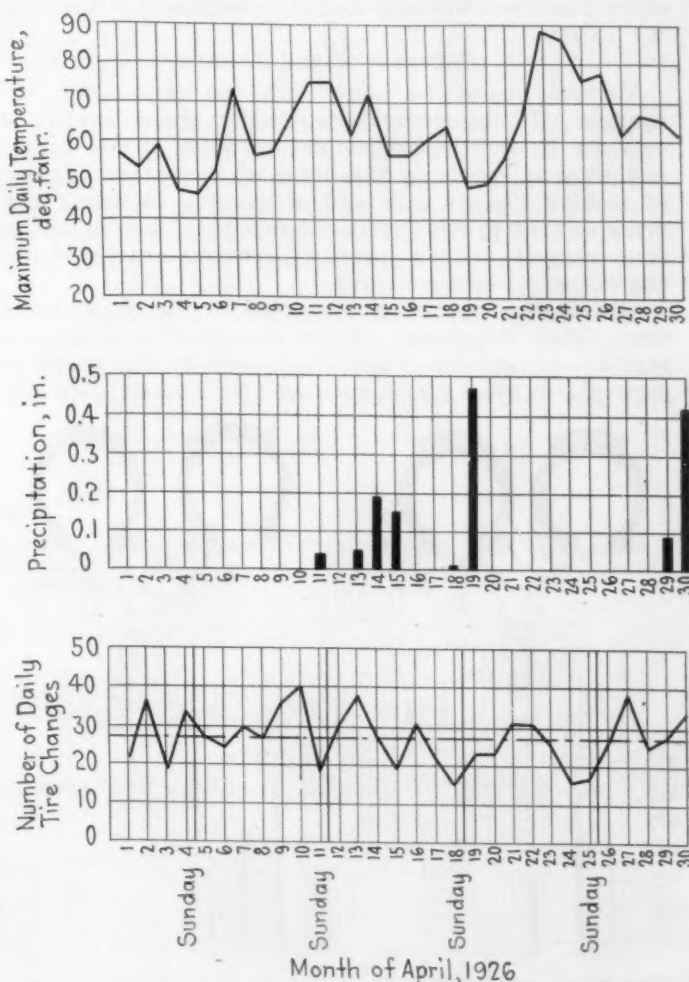


FIG. 6—STUDY OF THE EFFECT OF PRECIPITATION AND TEMPERATURE ON TIRE CHANGES

An Appreciable Quantity of Precipitation Occurred on Only 2 Days So That No Connection Could Be Established from That Angle. If the Chart Had Been Continued for 3 or 4 Months Longer, It Would Doubtless Have Reflected an Increase of Tire Trouble Similar to That Shown in Fig. 2

attributable to the motorcoach or the truck will be brought to light, for it has been our experience that misalignment of wheels, excessive heating of the brake-drum, interference between the tire valve-stem and the wheel, or even faulty brake-adjustment and operation will reflect themselves in an abnormal number of tire changes. This information is presented in Fig. 7.

Frequent mention has been made of brake-drum heat and its influence on tire performance. Considerable study has been given to this particular subject and some very interesting results have been obtained. The left half of Fig. 8 provides a fairly clear idea of the conditions found in a number of large motorcoach operations of both the city and the interurban types. Taking existing equipment, we found the brake-drum temperatures to be about 492 deg. fahr. above atmospheric, or 577 deg. fahr. actual. With such brake-drum temperatures, is it any wonder that tire beads are subjected to 301 deg.? It is needless to point out the destructive influence exerted on the rubber in the tire.

Considerable thought and study have been given to possible remedies for such conditions, but we are frank to admit that, with existing equipment, there does not seem to be much hope of relief. Indeed, merely increasing the wheel diameters cannot provide absolute freedom from such destructive temperatures. The most promising results have been obtained by the use of a wheel of larger diameter, as in the illustration of a 22-in. wheel on the right, which was used in conjunction with a baffle of sheet metal covered with asbestos between the brake-drum and the rim and acted as a deflector or shield for the rim and the tire. Note the temperatures obtained with this equipment. The tire bead shows only 179 deg. fahr., the baffle, 379 deg. fahr., whereas the brake-drum temperature remains, as in the first instance, about 577 deg. fahr. It has also been found that spoke wheels, acting in the capacity of a fan, have favorably affected these temperatures, as they provide more ventilation for the brake-drum.

EXCESSIVE BRAKE-DRUM TEMPERATURE

One of the interesting results of excessive brake-drum temperature was the great increase in the air-pressure

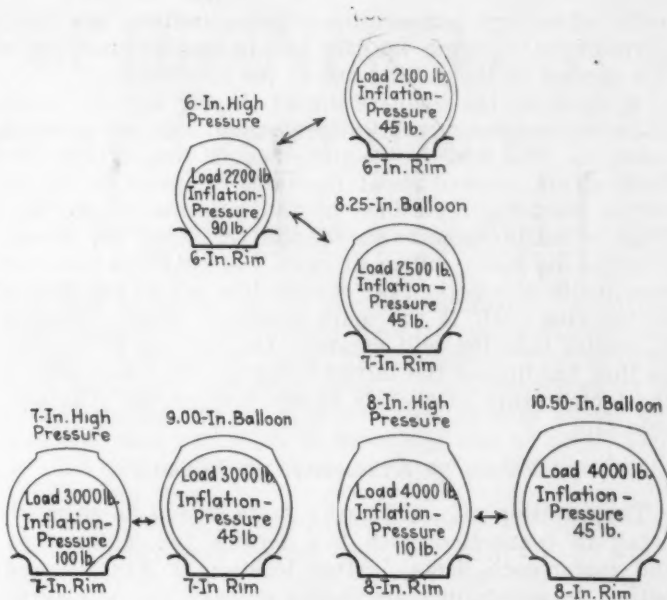


FIG. 11—BALLOON-TIRE REPLACEMENT CHART
The Four Sizes of Balloon Tire Most Likely to Come into General Use. The 6.00-In. High-Pressure Tire Can Be Replaced with a Low-Pressure Tire of 7.50-In. Cross-Section, for Which a Recommended Load of 2100 Lb. Is Indicated, or with One of 8.25-In. Cross-Section, for Which a Load of 2500 Lb. Is Recommended. The 7.00-In. High-Pressure Tire Is Replaced with the 9.00-In. Balloon-Tire Carrying the Same Load, 3000-Lb., as That Recommended for the Tire It Replaces, and the 8.00-In. High-Pressure Tire Is Replaced with the 10.50-In. Balloon-Tire Carrying 4000 Lb. Inflation of the Balloon Tire in Each Case Is Based on 45 Lb. per Sq. In. as Compared with 90 Lb. for the 6-In. Tire, 100 Lb. for the 7-Lb. Tire, and 110 Lb. for the 8-In. Tire

in the tire. When such destructive brake-drum temperatures are found, the initial, or, we might say, garage pressure, of the tires, when they start out in the morning, is likely to be considerably increased by the time the motorcoach returns in the evening, or just after the peak rush in traffic. According to Fig. 9, an initial pressure of 110 lb. per sq. in. in the inside tire was likely to develop into a pressure of 135 lb. per sq. in. later in the afternoon. Pressures much in excess of those plotted in Fig. 9 were found, some of them far beyond the margin of safety of the tire, when the rubber had been

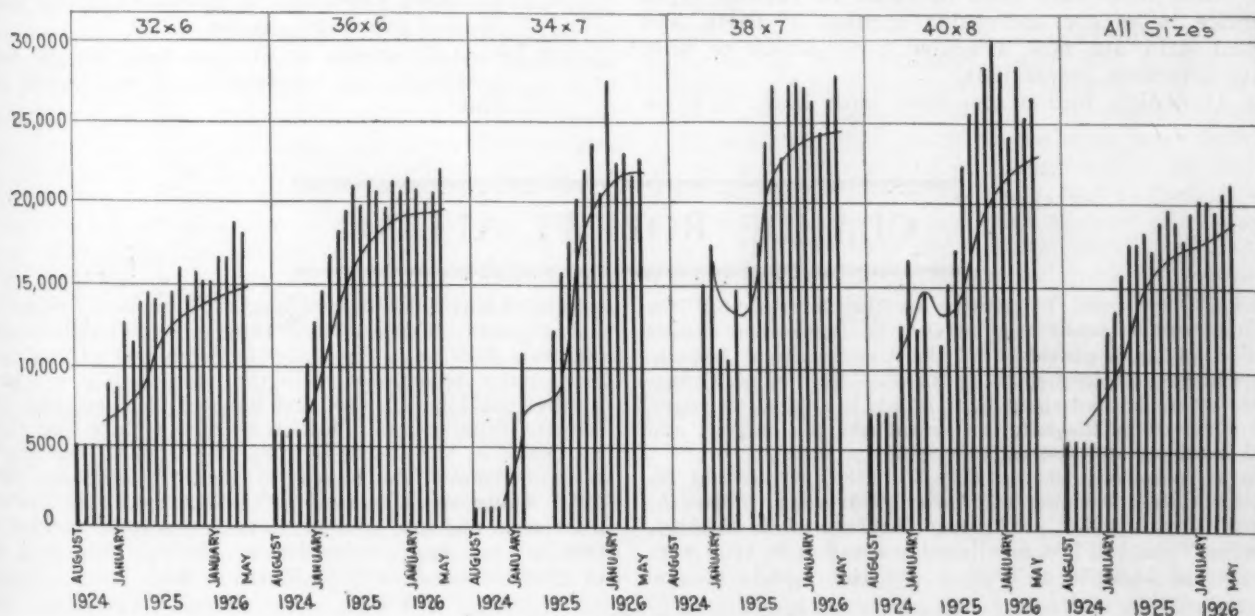


FIG. 10—PNEUMATIC-TIRE MILEAGE-REPORT
The Steady Increase in Tire Mileage Is Due to the Attention Paid to All the Factors Influencing Their Performance. In Addition to the Increase in the Average Accumulated Mileage Shown by the Curved Line Drawn through the Graphs, There Was a Decided Decrease in the Number of Road Delays Due to Tire and Tube Trouble

softened by high temperature. Such conditions are likely to result in bruising the tire and in the blowing out of the carcass or the pulling out of the tire beads.

A check on the temperature of the air in tires, when the motorcoaches return in the evening, was also of much interest. The rear inside tire, located directly over the brake-drum, showed about the same temperature as the air in its tube, regardless of the inflation of the tire. This is easily explainable by the fact that the brake-drum is its main source of heat. In contrast with the rear inside tire is the rear outside tire, where the flexing of the tire itself is the main source of heat. Increase of initial inflation will decrease the amount of flexing, so that the higher the initial inflation, the lower will be the temperature of the air in the tube of the rear outside tire.

VALUE OF ATTENTION TO DETAILS

The question may arise why there should be so much detail in connection with tire service for motor-truck and motorcoach fleets. After looking at Fig. 10 and noting the steady increase in tire mileage, you will agree with me that attention to all the factors influencing tire performance pays. In addition to the increase shown in the average accumulated mileage, as indicated by the curved line drawn through the graphs representing the monthly mileage on each size of tire, there was a decided decrease in the number of road delays due to tire and tube trouble. Not only was the tire bill of the operator greatly reduced, due to higher average mileage, but the road-service costs were cut in half, the schedules were maintained better and his efforts to sell satisfactory transportation to his patrons were aided considerably.

Probably the most recent as well as the most interesting development, insofar as pneumatic truck and motorcoach tires are concerned, is that of the balloon or low-pressure tire. Mention has already been made of the cushioning qualities of the pneumatic tire and of its widespread adoption as an aid to the automotive industry. In balloon tires of considerably larger cross-sectional dimensions and lower air-pressure, we have another decided step in that direction. During the last 3 years, these tires have been operated in various types of service in an ever-increasing number of fleets, and sufficient data are now available upon which to base definite favorable conclusions.

Fig. 11 depicts four of the sizes most likely to come

into general use. It will be noted that the existing 6.00-in. high-pressure tire can be replaced with a low-pressure tire of 7.50-in. cross-section, for which a recommended load of 2100 lb. is indicated, or it can be replaced with a low-pressure tire of 8.25-in. cross-section, for which a load of 2500 lb. is recommended. In the case of the 7.50-in. tire, we feel that its use should be confined to vehicles that are not overloaded when equipped with the present 6.00-in. tires and that, in the case of the 8.25-in. tire, the best results will be obtained when its use is confined to loads somewhat in excess of the 6.00-in. high-pressure load but lower than those of the next higher size.

The 7.00-in. high-pressure tire is replaced with the 9.00-in. balloon-tire carrying the same load, 3000 lb., as that recommended for the tire it replaces. The 8.00-in. high-pressure tire is replaced with the 10.50-in. balloon-tire carrying 4000 lb. Inflation in each case is based on a pressure of 45 lb. per sq. in. as compared with 90 lb. for the 6-in. tire, 100 lb. for the 7-in. tire and 110 lb. for the 8-in. tire. The three smaller sizes are now fairly generally used by motorcoach manufacturers as original equipment, while the 10.50-in. tires will very likely find their greatest field of usefulness on double-deck motorcoaches using the multi-wheel, or the so-called six-wheel, principle, or on trucks using 8.00-in. single tires. Other sizes are contemplated but as yet are confined to the development stage.

ADVANTAGES DERIVED FROM USE OF BALLOON TIRES

A few of the advantages, from the operator's point of view, that are to be obtained through the use of balloon tires are as follows:

- (1) More comfort for the passengers; hence, they are an aid to the sale of transportation
- (2) Lower mechanical up-keep, as they provide considerable cushioning for the vehicle
- (3) Greater ground-contact, thus providing greater traction and, at the same time, considerably less skidding
- (4) Increase in the average speed without an increase in the maximum speed of the vehicle, due to the fact that drivers do not need to slow-down for every rough spot in the road and can make sharper turns with greater safety
- (5) Probable increase in tire mileage; this, in some operations, has amounted to as much as 50 per cent

CLAUDE ROBERT ALLING

NEARLY 20 years of service in the interests of the Underwriters was closed on Oct. 25, 1926, when Claude Robert Alling, vice-president of the Underwriters' Laboratories, Chicago, succumbed to an illness. He died at Evanston, Ill., where he had spent most of his life, aged 42 years, and is survived by his wife, an infant son, his mother, and several brothers and sisters.

Born at Wilmette, Ill., on July 17, 1884, Mr. Alling received his college training at Denver University, at Northwestern University and at Armour Institute of Technology, graduating from the last mentioned institution in 1907 with the degree of bachelor of science. He immediately became

associated with the Underwriters' Laboratories, first as assistant engineer. From 1912 to 1918 he was division engineer, and from then until February, 1926, he was an engineer in the casualty department. The thorough manner in which he familiarized himself with and handled the problems in the different departments in which he served made him the logical choice of the Board of Directors when a vice-president was to be chosen, and he was so chosen in February, 1926.

Mr. Alling was a member of the National Fire Protection Association and also held active membership in various other technical and insurance societies. He was elected to Member grade in the Society on March 8, 1919.



Theory and Method of the New Haven Railroad's Highway Operation

By A. P. RUSSELL¹

TRANSPORTATION AND SERVICE MEETING PAPER

ABSTRACT

THE New Haven Railroad Company, having found, as the result of a survey, that competition by motorcoaches was seriously affecting its passenger revenue, took steps to protect itself. After several decisions of State supreme courts and of the United States Supreme Court had given the railroad company authority to operate motorcoaches over the highways, a subsidiary of the railroad, known as the New England Transportation Co., was formed. This company during the last summer has operated 37 through routes and utilized 168 motorcoaches, about one-half of which have been used in service superseding that of the railroad.

The policy adopted by the New Haven Railroad in the operation of its motorcoach lines is explained and the results that have been obtained are described. Better and more frequent service is said to be rendered at a considerable saving in the cost of operation per mile. The question of public necessity has been developed in the public mind to the point where it sees that this necessity affects not only the branch-line service but the very essential freight and through service that must be maintained in southern New England, if that section is to continue to prosper. The public now appreciates that whatever conserves established transportation organizations at the same time maintains permanent satisfactory transportation service.

AT the outset of any discussion dealing with the highway activities of the New York, New Haven and Hartford Railroad Co., it seems desirable to comment for a moment on the territory served by the New Haven System. It is almost too trite to warrant repetition to say that southern New England is the most highly developed industrial section of equivalent size in the United States. Not only has it many good-sized cities relatively close together, but these cities are connected by a system of highways equal to any to be found in the Country. It is a territory, therefore, that has lent itself readily to the transportation of passengers by motorcoaches; just how readily can be realized from the figures compiled as the result of a survey. These figures show that, in the territory served by the New Haven Railroad in the State of New York competitive highway coaches cover annually 1,500,000 miles; in the State of Connecticut, 20,000,000 miles; in the State of Rhode Island, 7,000,000 miles; and in the State of Massachusetts, 15,500,000 miles. To these figures must be added 48,000,000 miles of inter-State motorcoach operation each year. This total of road-miles operated in revenue service must reflect a carriage of passengers representing millions of dollars in revenue that is lost to the New Haven Railroad each year.

To approach the subject in another way: In the years preceding 1905, before this great increase in highway travel took place, figures show that the expectation of increase in business over the New Haven Railroad sys-

tem was in excess of 4.5 per cent annually. Applying that increase to the known figures, the indicated passenger-miles in 1923 should have exceeded 2,500,000,000. As a matter of fact, they fell about 775,000,000 short of this theoretical total. Compute this total at \$0.036 per mile and you will reach an estimated loss of about \$27,900,000 that is chargeable to highway competition in one form or another.

It is not to be expected that everyone will agree with these figures, even though they are the result of painstaking effort, but it is expected that everyone will agree that the situation reflected by them is sufficient justification for action by the New Haven system to protect its decreasing passenger-revenue.

At the close of the war, we found that the use of the highways, for the transportation of both passengers and freight, had been greatly increased. The principal reasons for the increase were, first, the desire of the Government to rid the railroads of as much unnecessary transportation as possible, in order that their services might be conserved for carrying out the purposes of the war; and, secondly, the inflation of prices and wages that enabled almost everyone to have the things that he had theretofore been denied. Shortly after, the method of transporting passengers by motorcoach became more and more common, even as the transportation of freight by truck had grown in the meantime.

Connecticut, as I remember it, was the first to recognize this means of transportation. She was the first of the New England States to pass a law placing under the Public Utilities Commission the regulation of motorcoaches on routes specified and approved by the Commission.

The street-railways of the Country, and particularly those in the New England States, had found that the methods of travel had greatly changed, and that their revenues were materially affected. It was not until 1921, 1922 and 1923 that the street-railways were authorized to use any other means of transportation on the highways than electric cars and rails; but at that time they were authorized to employ what we now call the motorcoach. The railroads had not been considered as an element in this means of transportation. But, because there were no laws governing the use of the highways by anyone who desired to use them, a form of transportation new to the public gradually developed and it had, as I have stated, a very serious effect upon the revenues and the service of the steam carriers.

MOTORCOACHES REPLACE RAIL SERVICE

Rhode Island had a law that it attempted to apply to inter-State operations until the United States Supreme Court rendered its decision, which virtually stated that there was no law governing inter-State transportation. The Supreme Court of Rhode Island, shortly after this United States Supreme Court decision, affirmed the right of the Public Utilities Commission to regulate intra-State transportation and stated, in effect, that the State

¹ Vice-president, New York, New Haven & Hartford Railroad Co.; president, New England Transportation Co., Boston.

had no right to interfere with inter-State transportation. We have a rule, therefore, in the State of Rhode Island that anyone desiring a certificate for inter-State transportation cannot be denied.

Massachusetts had what was known as the Jitney Law, which governed merely the transportation of passengers locally by hacks. It was not until 1925 that the law was amended so that the Public Utilities Commission took control of inter-State transportation between more distant points, and its regulation, through certificates of public convenience and necessity, was placed under the Public Utilities Department. Maine, for example, had no such law.

Then we were confronted by the decision of the United States Supreme Court to which I have referred, which stated that the States could neither regulate nor prevent inter-State transportation. From that sprung the desire of varied interests, the Public Utilities Association, the railroads, the street-railways, the Chamber of Commerce of the United States of America, the American Automobile Association, and in fact others interested in this great problem, to find a way so that there could be regulation of inter-State transportation. That matter is now pending in Congress, no action having been taken at the last session.

In Connecticut, we found that, because the public demanded this new form of highway transportation, the Connecticut Public Utilities Commission, following the law of that State and the decision of its Supreme Court upholding the theory that they were entitled to consider their certificates for public convenience and necessity as a monopoly, had granted certificates for routes that honeycombed the entire State. The railroad had no right to protect itself; the only thing left for it to do, as the patronage left it, was to decrease its train service.

Realizing that this condition was growing more and more acute, the president of the New Haven Railroad directed that a survey should be made. That survey developed, among other things, the figures with which this discussion opens and included a recommendation of what those who made the survey believed could be accomplished by undertaking highway operation, provided that authority could be obtained.

To coordinate and supplement rail and highway operation, final authority for a railroad to operate on the highways was received from the State of Massachusetts about the middle of June, 1925, Rhode Island and Connecticut having enacted similar legislation prior to that date. As soon as the authority to do so had been granted, a subsidiary company was formed, known as the New England Transportation Co.

MOTORCOACHES GREATLY REDUCE PER MILE COST OF OPERATION

Early in August, 1925, we installed our first line, in lieu of train service, on a branch in western Connecticut, with the result that a considerable saving over train service was effected. We found that we were substituting a means of transportation that cost substantially \$0.30 per mile in place of one that might average nearly \$1.25.

From then on, using the survey as a basis for deliberations, we proceeded with great care, and also with some haste, in an endeavor to find what would checkmate the enormous shrinkage in passenger revenues due to the operation of trains that were not earning their operating costs. Gradually, more and more lines were added until the summer of 1926 found us operating 37 routes

and utilizing 168 motorcoaches. Almost one-half of these routes take the place of train service.

In establishing these lines, we have adhered strictly to the policy laid down on Aug. 3, 1925, in a statement before the Massachusetts Public Utilities Commission. This statement has been published. It held that the transportation of the public rightfully belongs to the two great institutions that have expended the money of the public in building up a transportation machine: the railroads and the street-railways. It also held that we should be permitted to continue to perform the transportation service that the public seemed to demand, and that, where railroads and street-railways occupied a common territory, an understanding should be reached between them as to the revenues and expenses of the line operated there.

We have not run anybody off the road, nor have we followed the practice of indiscriminately purchasing established lines. We have, however, acquired four lines, one between Fall River, Mass., and Providence, R. I., one between Providence, R. I., and Willimantic, Conn., one between Hartford, Conn., and Westfield, Mass., and one between Hartford and Willimantic, Conn. If any operator has gone out of business, it has been because he could not maintain service at the standard railroad fare, or because he could not conform to the law. When anyone has received a certificate from the regulatory bodies and has been respecting the law, we feel that he has a right to operate.

MOTORCOACHES OPERATED AT RAILROAD RATES

We have maintained substantially the rail rates. On lines that have supplanted railroad service, we have taken over the entire New Haven obligation and have collected all classes of fares, local, commutation and 25-ride tickets, on the railroad basis.

In establishing our schedules, we have paralleled as nearly as possible the railroad schedule, in many cases offering extra trips to eliminate double-heading. Aside from providing a regular schedule, we have endeavored to give slightly more service.

Where highway lines supplement railroad service, it is evident that any supplemental service is bound to be more or less in competition with that of the railroad between certain points. As a general thing, however, we reach places that have not had what might be considered as satisfactory rail service and are regaining travelers who had sought other means of transportation. Mail, newspapers, baggage, express, and milk offer interesting problems, too complicated, however, to be discussed in a general statement of this sort.

Of the 168 motorcoaches, all but 27 are of the de luxe parlor-car type. Twenty-seven are semi-de luxe. Of the 168 coaches, 60 have four-cylinder and the remainder six-cylinder engines. These coaches make about 438,000 road-miles per month and carry approximately 235,000 passengers. The average length of the routes is 28 miles; the shortest being 3; the longest, 60 miles. Our operating cost per mile can conservatively be said to be \$0.30.

To govern the operation, we have a standard set of operating rules. We also have a complete set of rules for the guidance of coach operators in handling the revenues and the reports of traffic data.

MOTORCOACH MAINTENANCE

Naturally, this fleet of 168 coaches was not all acquired at once; in fact, the maximum was not reached until early in the summer of 1926; consequently, our

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mechanical department was the last to be developed. Providence, R. I., is a large operating center. As the lines were developed, the equipment was housed in local garages in small numbers. Later, a larger garage was rented in Providence but, the demands of the business not having been anticipated, the capacity of that garage has already been exceeded. We are at present building a garage and heavy repair-shop in Providence that will be about 140 ft. wide and a little more than 400 ft. long.

We anticipate that this shop will take care of 80 motorcoaches and will have sufficient capacity to overhaul all the vehicles owned by the company. The garaging, daily inspection and light work in connection with inspection are being handled in the State of Connecticut by the Connecticut Co., which is also a subsidiary of the New Haven Railroad and which has, through its own motorcoach operations, established garage facilities.

I think I have said enough to give you a picture of what started the New Haven Railroad in highway transportation and how we have developed this feature. We believe that our judgment is sound. We are not over-

confident. We feel, however, that if we had not gone into highway transportation when we did, our losses in passenger revenue would have been even more serious. We are confident, therefore, to the extent of having overcome that threatened condition.

Moreover, we feel that the public believes we have taken the right stand in giving a better and more frequent service, and one that results in a considerable saving per mile of operation. It is generally recognized that whatever weakens railroad revenues affects the integrity of railroad service. The question of public necessity has therefore been developed in the public mind to the point where they see necessity as a broad word that affects not only branch-line service but the very essential freight and through service that must be maintained in southern New England, if the territory is to continue to prosper. Viewed from that standpoint, we believe the public now appreciates that whatever conserves established transportation organizations, at the same time guarantees permanent satisfactory transportation service.

GROWTH OF A NEW WORLD ECONOMY

A TREND in the direction of a world economy, in which all nations will prosper or suffer together, is discoverable today. That the great financial crises have an international sweep has long been recognized. Thus, England and the United States and France shared in the crises of 1815, 1825 and 1837; England, the United States and France shared in the crisis of 1847; these three countries, and Germany also, shared in the panic of 1857; and England, the United States, France, Germany, and Austria shared in varying degrees the crisis of 1873. All five countries had mild recessions in 1882 to 1884. After 1890, of the 17 countries included in the annals, which were compiled by Dr. Willard L. Thorp from records extending in some cases as far back as 1790, 10 had recessions in 1890 and 1891, 15 had recessions in 1900 and 1901, 15 in 1907 and 1908, 12 in 1912 and 1913, 11 in 1918, and 14 in 1920.

Further, the countries that escaped a share in these world reactions usually owed their exemption to still worse fortune. Thus South Africa and Japan had no recessions in 1900 and 1901 because they were already suffering from depression. The three countries of our 17 which escaped in 1920 were Germany, Austria and Russia.

In 1873 the United States, Germany and Austria suffered far more severely than England and France. In 1890, on the contrary, the financial strain was more severe in London than in New York City or Berlin, while Vienna deferred its recession until 1892.

The center of disturbance in 1900 seems to have been Germany; countries like the United States and Italy felt but repercussions of a foreign shock. In 1907 the gravest difficulties appeared in the United States.

Probably the nearest approach to a severe worldwide crisis was made in 1920, and that case was obviously dominated by post-war readjustments. That a financial crisis breaking out in any country of commercial importance produces financial strains in other countries and that even mild recessions like those of 1882 and 1883 and 1913 spread widely, is, however, clear.

INFLUENCE OF DEGREE OF ECONOMIC ORGANIZATION

The countries whose business cycles diverge most from the international pattern are Italy before say 1907, Russia, South Africa, Brazil, and China, all countries rather backward in economic organization and predominantly agricultural. The countries whose cycles have followed the international pat-

tern most closely, on the other hand, are countries of highly developed industry, trade, and finance; England, France, Germany until 1919, Sweden, and the Netherlands. Australia and Canada lag but a little behind these European powers in conformity.

Whatever the causes of the recurrent fluctuations in economic activity may be, the annals suggest that these causes become active in all communities where an economic organization approximating that of western Europe has developed. A rough parallelism between the stage attained in the evolution of this organization by different countries and the prominence of business cycles as a factor in their fortunes appears to exist.

One characteristic of the type of organization in question is the wide area over which it integrates and coordinates economic activities. Bare as they are and short their span, the annals reveal a secular trend toward territorial expansion of business relations and a concomitant trend toward economic unity. For example, the American annals show how often the fortunes of the North, South and the West diverged from one another in the earlier decades after the adoption of the Constitution and how these divergencies have diminished in later decades.

UNITY OF FORTUNE

Not that business is ever equally prosperous or equally depressed in all States of the Union even now; perceptible differences always are found, and at times the differences are wide, particularly among the great farming belts. Yet the annals picture the vastly greater population of today, spread over a vastly greater territory, as having more unity of fortune than had the people of the 13 original States and the frontier settlements that were established in the period from 1790 to 1820.

Broadly speaking, the annals support a similar conclusion for the world at large. The network of business relations has been growing closer and firmer, at the same time that it has been stretching over wider areas.

As American business is coming to have one story, diversified by agricultural episodes, so, before the war shattered international bonds for a time, world business seemed to be approaching the time when it too would have one story, diversified by political and social as well as agricultural episodes in different countries.—Dr. Wesley C. Mitchell, director of research of the National Bureau of Economic Research.

Engine Characteristics as Affected by Cylinder and Crankcase Arrangement

By H. M. CRANE¹

METROPOLITAN SECTION PAPER

Illustrated with CHARTS

ABSTRACT

AFTER outlining his experiences with primitive types of automobile engine from the time of the single-cylinder Oldsmobile runabout with curved dash, the 2-cylinder Peerless, the 4-cylinder Pierce, and thence successively through the various types of 6 and 8-cylinder engines and the 9-cylinder radial up to the 12-cylinder Packard, the author explains the characteristics and advantages of each type and the reasons for its vogue. He then endeavors to look into the future to determine, if possible, what the salable article will be several years hence. The course of engine development, though due to definite and plain causes not always understood at the time, is now easily recognizable, and attention is called to the characteristic features of various types of present-day engine and the trend of modern design.

The single-cylinder engine was naturally the first to drop by the wayside, because the two-cylinder-opposed engine could be built for practically the same cost per horsepower and gave more satisfactory service. This was followed by the vertical four-cylinder type, because of its inherent economy in manufacture and operation. Desire for greater smoothness of operation and freedom from vibration then led to the extensive use of the six-cylinder engine. Efforts to improve the running balance subsequently caused the appearance of various types of 8 and 12-cylinder engines and the 9-cylinder radial.

Assuming that it is equally easy to connect any number of cylinders, from one up, to the driving system and that the object is to obtain a certain horsepower, the exact amount not being important, drawings were prepared, based on the consideration of an engine of 300-cu. in. displacement divided into one or more cylinders, the parts being, as nearly as possible, correctly proportioned for each size of cylinder. From these drawings a detailed study was made of the advantages and disadvantages of each type of engine as deduced from an examination of the valve problems, valve-spring pressures, capacity for high speed with various numbers of cylinders and other considerations. A gain in ability to fill the cylinders fully and higher maximum speed are shown to follow as the number of cylinders is increased. Admitting that the multi-cylinder engine has obvious advantages, an investigation is then made as to how many cylinders should be used and of the best manner of coupling them to the driving-shaft to obtain the desired result, for the method of coupling the cylinders to the driving-shaft has a very important effect on the smoothness of running of the engine and also on the maximum power obtainable from the cylinders themselves.

Careful consideration is given to the subject of noise due to vibration of the engine. These vibrations are said to be due mainly to change of position of the center of gravity of the engine, including all its moving parts, the balancing planes of which, with the exception of that of the radial-type engine, are more or less separated. Unless the structure is perfectly rigid, which is of course impossible, other types of

vibration are set up that, under some conditions, become more unpleasant than ordinary free vibration. Other vibrations are produced by the springing of the crankshaft under the increased loads when operating at high speed, a cause that is accentuated by certain types of cylinder hook-up, and by torque reaction. Frequently, efforts to reduce vibrations from one source increase those from another. Variation in torque reaction is said to be produced by variations in the type of explosion and to cause so-called roughness, which appears as a shuddering feeling and is often accompanied by distinct bumping. Roughness is also affected by the quality of the fuel mixture.

Schematic drawings of various types of engine having from 1 to 9 cylinders are presented, the 12-cylinder V-type engine, the characteristics of which are almost identical with those of the 6-cylinder engine, being omitted because the former is not used in commercial motor-cars at the present time. The drawings bring out the limiting qualities of different cylinder and crankshaft arrangements, the details of which are indicated in the captions.

I HAVE been looking for light on some interesting questions that are before anyone designing passenger-cars at the present time. I have seen a little light in certain directions and will try to place before you the course of my investigation. It happens to be almost exactly 20 years since I entered the motor-car business and 25 years since I first drove a car propelled by a gasoline engine. The car in question was an Oldsmobile runabout having a curved dash and a single-cylinder engine. Since that time the number of cylinders used commercially in motor-car engines has continually increased until it reached at least a temporary maximum at the 12-cylinder mark shortly after the war.

The first car I owned was a single-cylinder United States Long Distance runabout. The shortest thing about that car was the time between overhauls. I remember still a strenuous run of about 30 miles at 25 m.p.h. from Oyster Bay, N. Y., to New York City, after which we spent hours in service stations searching for spare parts to replace those that had been left along the road. About once a week we had to remove the brass box of the crankpin bearing and put it into a shaping machine to take off $\frac{1}{8}$ in. The second car was a two-cylinder Peerless having a vertical engine with the cranks together and equally spaced explosions. The third was a four-cylinder Pierce, which I owned at the time of going into the motor-car business.

TWO-CYLINDER-OPPOSED ENGINES

You will remember that the Cadillac made a very successful start with a single-cylinder engine, and that in 1903 two-cylinder engines were very common. The Pierce used a vertical engine with the cranks set opposite and having unequally spaced explosions, while Winton and Autocar used engines of the double-opposed type, the former having the engine under the hood, as is common practice today, and the latter having the engine in the

¹ M.S.A.E.—Technical assistant to the president, General Motors Corporation, New York City.

center of the car with the crankshaft crosswise and a chain drive to the rear axle. Numerous other examples of the double-opposed type were in use about this time, but I think that the Autocar is the only company that still retains the original type then selected.

THE VERTICAL FOUR-CYLINDER TYPE

About that time the vertical four-cylinder engine was built in commercial quantities and was supposed to represent the height of luxury. One or two companies paused at the three-cylinder vertical type with equally spaced crankpins, my recollection being that Panhard and Thomas were in this list. This type of engine is interesting only as having been the forerunner of the six-cylinder type, now so commonly used. As I recollect it, a very distinct pause in the advance in the number of cylinders occurred after the four-cylinder type came into general use, but eventually the possible merits of six-cylinder engines began to be discussed. The four-cylinder engine has always suffered from a certain amount of free vibration due to the angularity of the connecting rods, which prevents the exact balancing of the reciprocating forces. The three-cylinder engine would have been satisfactory in this respect if the cylinders could have been located in a single transverse plane. With the cylinders spread along the crankshaft, a rocking couple developed. Obviously, by placing two three-cylinder engines end to end in one crankcase, the rocking couples will neutralize one another and the free forces will be largely eliminated.

DIFFICULTIES OF THE SIX-CYLINDER ENGINE

By 1912, the six-cylinder type had attained an important place in the production of high-priced cars. It failed, however, to solve all the vibration difficulties, for reasons that are now well known and to which I shall refer later. The six-cylinder engine also was difficult to handle in manifolding and carburetion and had greater length and weight than the four-cylinder type. Many engineers believed that a solution might be found in

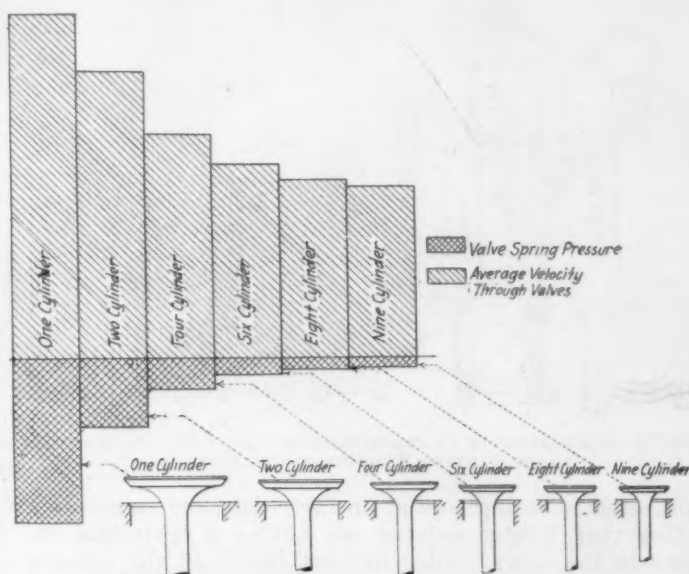


FIG. 2—COMPARISON OF VALVES FOR ENGINES HAVING 300-CU. IN. DISPLACEMENT AND VARYING NUMBERS OF CYLINDERS

The Two Series of Blocks Represent the Valve-Spring Pressure and the Average Velocity through the Valves in Feet per Second at the Same Engine-Speed. The Bore and Stroke Are Equal; the Valve Diameter Is Proportioned to the Diameter of the Cylinder; the Lift Is One-Quarter of the Valve Diameter. All Calculations Are Figured at 2500 R.P.M.

adopting the eight-cylinder V-type engine, which consisted of two four-cylinder engines with the cylinders set at 90 deg. on a single crankshaft. An engine of this type, which had been applied to a motor-car in this Country as early as 1908 by E. R. Hewitt, produced interesting results, as I can testify from personal experience. Not until a number of years later, however, did this type come into commercial use, first in Europe and then in this Country, when Cadillac based its whole production program on a V-type eight. Experience with this type showed that the problem of vibration was still unsolved and that the engine could not be expected, in the long run, to equal the possibilities of the six-cylinder type.

THE PACKARD TWELVE

The next move, a logical one, was for the Packard Company to try out the 12-cylinder V-type engine, consisting of two six-cylinder engines having the cylinders set at 60 deg. and operating on a single crankshaft. If much greater power should be needed in motor-car engines, this type possibly might make a place for itself, but, in displacements of less than 500 cu. in., it is expensive and complicated in construction and operation and offers very slight advantage, if any, in performance over several types of engines having fewer cylinders.

Subsequently to the appearance of the 12-cylinder V-type engine several modifications of the 8-cylinder type came into commercial use. The Lincoln car adopted a V-type engine with the cylinders set at 60 deg., in the belief that an improvement in the vibration characteristics would be obtained in this manner.

EIGHT-CYLINDER TYPES

The eight-cylinder straight-line engine also began to be adopted in the commercial production of motor-cars. This type cannot be said to be particularly novel, for it was used in high-powered motorboats at least 20 years ago. Variations in the arrangement of crank-throws are possible on this type of engine and the apparently available ones are now in commercial use. It is fair to say that the eight-cylinder straight-line type of engine was

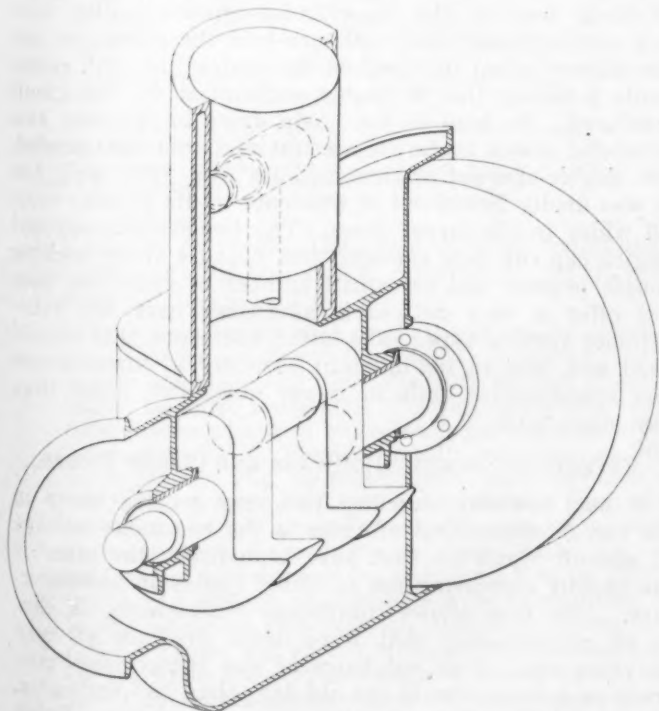


FIG. 1—TYPICAL SINGLE-CYLINDER ENGINE

The One Illustrated Has a $7\frac{1}{4} \times 7\frac{1}{4}$ -In. Cylinder, $2\frac{3}{4}$ -In. Valve Ports, and 300-Cu. In. Displacement

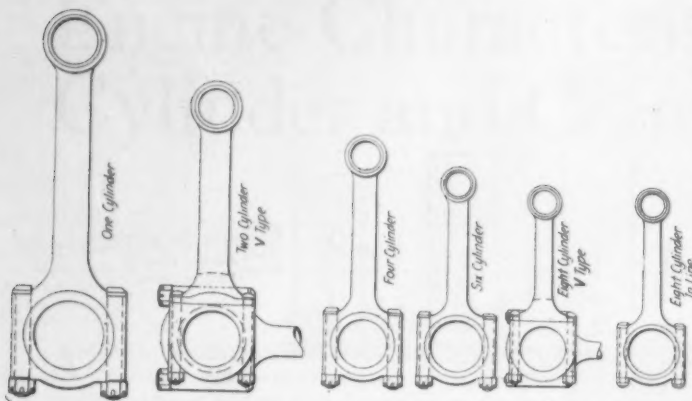


FIG. 3—COMPARISON OF CONNECTING-RODS FOR 300-CU. IN. ENGINES OF VARYING NUMBERS OF CYLINDERS

also used in racing cars at an early date, my recollection being that Winton entered one having a horizontal engine in the Irish Gordon-Bennett race. As the demand for the smoother running of engines at high speed brought an intensive study of the various available types and it was shown that the eight-cylinder 90-deg. V-type engine might be given a highly satisfactory balance by setting the crankpins at 90 deg. and counterweighting them locally, this type of engine was adopted by the Cadillac Company. A similar arrangement, I understand, was used later by Peerless.

THE NINE-CYLINDER RADIAL

Still another type of engine has had very little commercial application in motor-cars, although it is highly successful as an aviation engine. This is the radial-type engine having all the three, five, seven or nine cylinders operating on a single crankpin. Engines of this type, I believe, are used in a few small cars abroad but the layout is nearly impossible to apply to automobiles of conventional design.

During all these years the increase in the average number of revolutions of the engine per car-mile on the direct drive had been steady. The pressure in favor of this has been threefold: first, a steady increase in the weights of cars used for similar kinds of service; secondly, an attempt to reduce the weight of the powerplant by taking full advantage of smoother-running engine-types; and, thirdly, a demand for more rapid acceleration and better hill-climbing performance in high gear. In the old days, any car attempting high-speed performance was geared so that the engine made from 2 to $2\frac{1}{2}$ turns to each turn of the rear wheels, or from 1100 to 1300 revolutions per mile. Today, cars in commercial produc-

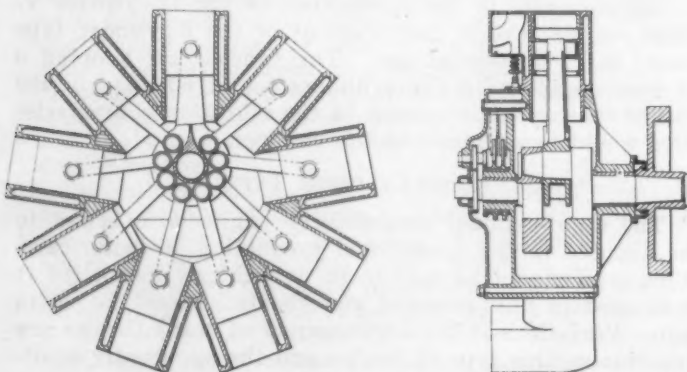


FIG. 4—NINE-CYLINDER RADIAL-TYPE ENGINE
Displacement, 300 Cu. In.; Cylinders, 3.48 x 3.48 In.; Valve Port, $1\frac{1}{4}$ In. The Firing-Order Is 1-3-5-7-9-2-4-6-8

tion require about 3000 revolutions per mile. The facts already stated are probably well known but I have restated them to provide a starting-point for further study of the subject.

The motor-car business has grown to such enormous size and the production of a new model involves so large an expenditure for tools, as well as for the cost of development, that to look into the future is more important than ever to try to determine, if possible, what the salable article will be several years hence. I think I can show that the course of engine development along the lines described was the product of very definite and plain causes that are easy to recognize now but were not always understood at the time.

CRUDE MANUFACTURING METHODS

In the early days, the use of the minimum number of cylinders was strongly favored for many engineering and manufacturing reasons. In those days, to get reliable castings for individual cylinders, or for complicated crankcase designs was hard. Methods of carburetion and manifolding were little understood and crude, and electric ignition was very unreliable in all its various parts, such as the coils, commutators, magnetos, spark-plugs, and wires. Crude manufacturing methods made it far more economical to turn out a few large pieces than a larger number of smaller pieces. Moreover, the power demanded by the public was not great, speeds were low and flexibility was not expected; body construction was of the simplest; there were no windshields or doors, tires were hard and roads were rough, making engine vibration almost unnoticeable to passengers, not to mention the fact that absence of windshields allowed a free rush of air, which is certainly wonderful for masking any noise from the engine. The engine had to be very noisy in one of those cars before much attention was paid to it.

Naturally, the single-cylinder engine was the first to drop by the wayside, because a two-cylinder-opposed engine could be built for practically the same cost per horsepower and would give more satisfactory service. Without question the two-cylinder-opposed engine, having each cylinder cast with one-half the crankcase and the halves bolted together on the center line, still represents a design that is highly economical for the result produced. So long as the chain drive to the rear axle persisted and a moderate amount of power was needed, the double-opposed engine held its own very well, but it was finally forced out of existence by its greater overall width in the larger sizes. The two-cylinder-opposed engine can run very smoothly but, because of the rocking couple present and the small number of cylinders, does not offer a very noticeable advantage over the four-cylinder vertical type. The latter, therefore, was largely used and, due to its inherent economy in manufacture and operation, is built in larger quantities today than any other type.

EFFECTS OF SMOOTH HIGHWAYS AND CLOSED BODIES

It has, however, received two very serious blows in the last 5 years. One of these is the enormous mileage of smooth highways that have been built; the other is the rapidly increasing use of closed bodies on passenger-cars. The first allows continuous road-speeds, in cars of all price-classes, that were never dreamed of even 15 years ago. I do not know of any better speed-governor on a motor-car in the old days than bad springing. That was true of nearly all cars at that time. Today many miles of concrete highway are so good that springs are of no value, for the tires supply all the spring that

is needed to give very easy riding. Higher speeds, especially in long-distance travel, emphasize in a very drastic way any defects in the powerplant that cause vibration.

A closed body, especially if it is of economical construction, acts as an amplifier of all kinds of vibration and emphasizes the deficiencies brought to notice by a higher car-speed. The coach type of body, for instance, with its large floor-space almost unobstructed, its large window areas not broken up and its large panels of all kinds, is probably one of the hardest bodies that can be imagined to which to fit a chassis and have quiet operation.

The important question is bound to arise in a low-priced car, whether it is cheaper to make the body of less noise-amplifying construction, or to use a more smoothly running powerplant; and that question has not been determined yet. It is one of the interesting features of the business; and the answer will be, how extensively the six-cylinder engine is used in the lower-priced classes and how large its production becomes.

REASONS FOR POPULARITY OF SIX-CYLINDER ENGINE

In an article published about 2 years ago, I called attention to the amplification of vibration by closed bodies and the emphasizing of deficiencies by higher car-speed,

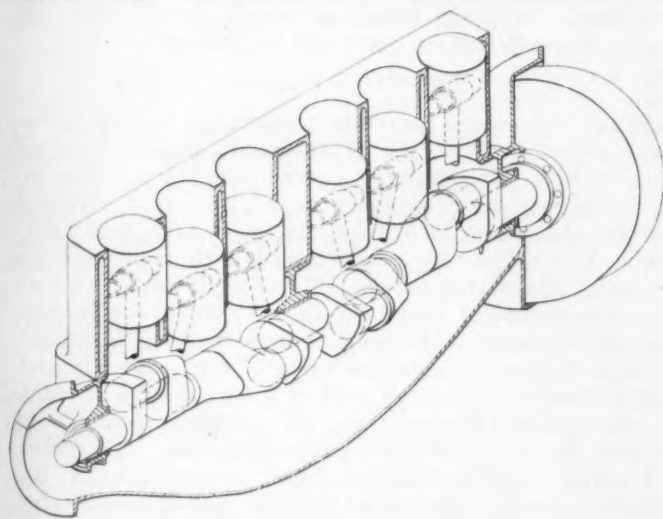


FIG. 5—SIX-CYLINDER THREE-BEARING ENGINE

Displacement, 300 Cu. In.; Cylinders, 3.99 x 3.99 In.; Valve Port, 1½ In. Firing-Orders: Cranks No. 2 and No. 5 Following No. 1 and No. 6, 1-5-3-6-2-4; Cranks No. 2 and No. 5 Leading No. 1 and No. 6, 1-4-2-6-3-5

but did not emphasize the effect of road conditions on the problem. In the article referred to the following statement appears:

The reason for the wide popularity of the six-cylinder type is its smoothness of operation at all engine-speeds and its high degree of flexibility. It is still the simplest engine in which mechanical vibration has been practically eliminated and in which the power impulses overlap sufficiently to provide smooth operation at the lower speeds. The American public today demands a car having a high degree of ability in high gear; and this means either a very large engine or rather high engine-speed at the normal road-speeds of the car. A six-cylinder engine meets this requirement by its ability to run fast without objectionable noise or vibration. It is interesting to note that the popularity of the six-cylinder engine has greatly increased in connection with the increased use of closed bodies. This is due to the fact that vibration which does not seem objectionable in an open car is liable to be unpleasantly noticeable

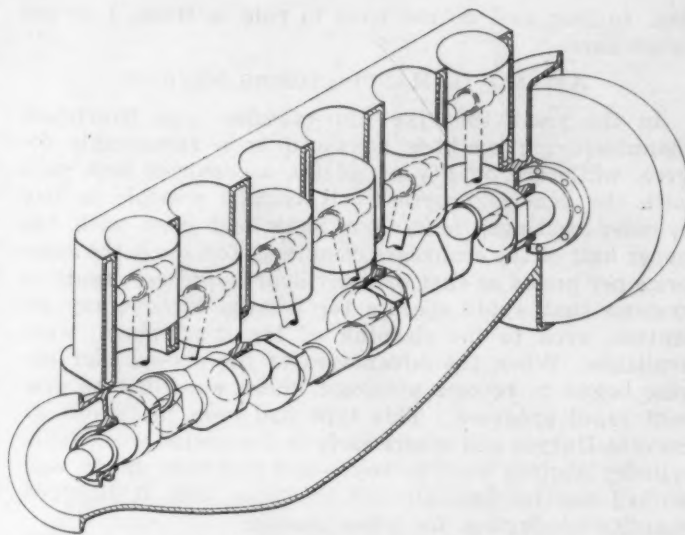


FIG. 6—SIX-CYLINDER FOUR-BEARING ENGINE

Displacement, Dimensions of the Cylinder, and Diameter of Valve Port Are the Same as Those of Fig. 5

in a sedan or limousine because of the sounding-board effect of the body. I look for a still further extension of the six-cylinder type into the low-price field, but I doubt that it can ever take the place of the four-cylinder engine in the lowest-price class.

The increasing preponderance of the closed body has in itself been sufficient to cause an invasion of all but the very lowest-price classes of passenger-car by the six-cylinder engine or by some other type of powerplant having equally good characteristics so far as vibration is concerned. In addition, the effect of improved highways has been increasingly noticeable in the last 2 or 3 years. The change is so great from year to year that we do not know even now how far it will go. The whole attitude of the public toward what it expects of an automobile is changing.

In the old days, if a car ran comfortably up to 30 or 35 m.p.h. without undue noise or vibration, practically any owner, except a few of the "speed-merchant" class, would be satisfied. Today, it seems necessary to give real comfort at 40 or 45 m.p.h., and even higher speeds are distinctly common. I have heard some prognostications that motorcoaches will be geared up to 100 m.p.h.

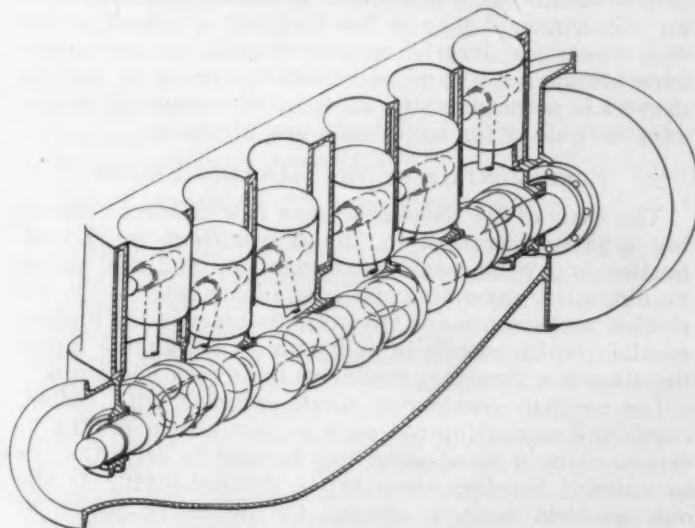


FIG. 7—SIX-CYLINDER SEVEN-BEARING ENGINE

Displacement, Dimensions of the Cylinder, and Diameter of the Valve Port Are the Same as Those of Fig. 5

² See *Motor*, January, 1924, p. 121.

but, so long as I do not have to ride in them, I do not much care.

ADVANCE IN MANUFACTURING METHODS

In the years that the four-cylinder type flourished, manufacturing methods advanced in a remarkable degree, while the quality of all the accessories kept pace with the general progress. It became possible to buy cylinder castings, four in a block and even with the upper half of the crankcase combined, for about the same price per pound as that of individual cylinders. Ignition systems that would operate for months without any attention, even to the cleaning of the spark-plugs, were available. When the advantages of the six-cylinder engine began to become apparent, there was little to prevent rapid progress. This type had been pioneered by Stevens-Duryea and others early in the period when four-cylinder engines were in vogue and had been fairly well worked out mechanically by the time that it justified quantity production for other reasons.

Whether rightly or wrongly, I have always felt that some of the qualities provided in Packard cars in the years 1906, 1907 and 1908 pointed the way to the performance characteristics that are now almost universal, due to public demand. These Packards were of moderate weight but had very large engines, together with what at that time was a very large reduction in the rear-axle gearing. The engine, though large, had low compression and slow-speed timing. This combination provided good low-speed performance, excellent hill-climbing ability in high gear and rapid acceleration, together with very smooth operation for that period. I can assure you from personal tests that the 1908 Packard was a better climber in high gear than most commercial motor-cars up to 2 or 3 years ago.

About my first independent order for a motor-car came from an enthusiastic Packard owner who wanted "more of the same thing." The obvious answer seemed to me to be the six-cylinder engine; and in the fall of 1908 I began my first design with a confidence born of a pretty complete ignorance of some of the difficult problems involved.

A friend of mine says he thinks the greatest thing for a speaker to do is to tell of all the mistakes he has made and why he has made them. The only trouble is that this meeting must end at 10 o'clock. I have a gallery of manifolds that I think is beyond competition by any experimental shop in this Country. I intend to base this discussion largely on powerplants for passenger-cars, although the same considerations apply in varying degrees to powerplants for all types of commercial motor-cars, as well as for motorboats and airplanes.

FUNDAMENTALS OF THE GASOLINE ENGINE

The basis of the gasoline engine is a cylinder containing a piston operated by the intermittent rapid combustion of a compressed mixture of air and fuel vapor. To obtain the maximum efficiency in combustion, the explosion temperature and the pressure must be the highest possible, which results in supplying to the engine initial impulses in a form not conducive to smooth operation.

Let us then consider a single cylinder with piston, crank and connecting-rod such as that shown in Fig. 1. One or more of these units may be used to drive the car by suitably coupling them to the driving-shaft. If the only problem were to provide the necessary power to produce a given result at the lowest cost, the answer would be much easier to determine. The public, however, is demanding, and I think rightly, that the power-

plant shall be as unobtrusive as possible, except in its effect in moving the car. The ordinary car-user thoroughly enjoys the feeling produced by very rapid acceleration, but the less this is accompanied by noise or vibration, the more satisfactory will the result be considered. To prevent engineers from becoming too well satisfied with their product, it is suggested that an occasional coast down a 5-per cent grade with the engine shut-down will convince them that something still remains to be attained.

Let us begin our consideration by assuming that to connect any number of cylinders, from one up, to the driving system is equally easy, and that we are aiming to obtain a certain horsepower, the exact amount not being important. The power that can be obtained from a single cylinder depends on the size of the charge that can be properly drawn in, compressed and fired for each power stroke, and upon the number of these charges that can be handled per minute. We then find that two important limiting features must be considered: first, the ability of the cylinder to draw in a charge and, secondly, its mechanical ability to operate at a large number of revolutions per minute. Several drawings have been prepared, based on a consideration of an engine of 300-cu. in. displacement divided into one or more cylinders, the parts being, as nearly as possible, correctly proportioned for each size of cylinder.

THE VALVE PROBLEM

Fig. 2 represents the valve problem on several different types of engine, each of 300-cu. in. displacement but with varying numbers of cylinders. At the extreme left is a single-cylinder engine; the next is a two-cylinder engine; the others have four, six, eight, and nine cylinders. The valves are proportioned with approximately the same dimensions for the different cylinders. In each case, the ordinates above the line represent the velocity through the valve at the same engine-speed. The velocity is much higher through the valve of the single-cylinder engine than it is through that of a two, four, six, eight, or nine-cylinder engine. As the cylinders increase in number, the difference becomes less marked. The reason is a purely mathematical one, based on the fact that the cylinder capacity enlarges as the cube and the valve area directly as the square of the diameter. Below the horizontal line is shown the valve-spring pressure necessary to operate the valves at the engine-speed used for purposes of study, namely, 2500 r.p.m. Even with the under-size valve in the single-cylinder engine that is not really capable of allowing the cylinder to fill when pumping at high speed, a very high spring-pressure is required to operate the valve. These ordinates are in proportion to the actual valves. No definite quantity is given, but the spring pressure on the single-cylinder engine is more than 10 times the spring pressure required on the nine-cylinder engine to accomplish the desired result. It is fairly obvious from a study of this kind that an increase in the number of cylinders conduces to an easier filling of the cylinder and probably, therefore, to a higher speed of operation.

CONNECTING-RODS

Fig. 3 shows the connecting-rods of these hypothetical engines, including the single-cylinder engine of 300-cu. in. capacity, the eight-in-line, a two-cylinder V-type with both rods connected with the same crankpin, and the four and six-cylinder engines. The drawing seems to indicate that the single-cylinder engine would probably not be capable of the high speeds of revolution that are

possible with engines having a greater number of cylinders and the same piston-displacement. As I said at the beginning, it is necessary to fill the cylinder and also, if possible, due to mechanical reasons, to fill it the maximum number of times per minute.

From these drawings you will see a very rapid gain in both the important qualities as the number of cylinders is increased. Not only is it possible to fill a small cylinder fully at a much higher speed than to fill a large cylinder but, equally, the maximum speed based on mechanical reasons will also be higher. Of course, we have added to this the ability of the smaller cylinder to run at somewhat higher compression due to more favorable detonation characteristics, against which should be set off the fact that leakage in a small cylinder is considerably more important and that the frictional losses will be relatively higher.

PUMPING LOSS

One of the big mechanical losses, the largest by far in a thoroughly warmed-up engine operating at part throttle, is the pumping loss, and the pumping loss should not be affected by the number of cylinders. It is conceivable that, if the smaller cylinders produced a higher torque and therefore allowed a better rear-axle ratio for a given hill-climbing ability, the pumping loss might be even less. In other words, it is not necessarily true that a small number of large cylinders will show a great gain in so-called mechanical efficiency at ordinary road-speeds, because in such speeds the pumping loss is the big item. By pumping loss is meant the fact that, in a four-cycle engine, an attempt is made to draw in a charge against a closed throttle. If an indicator is placed on the manifold, a considerable depression will be found in the manifold, and this acts on every piston during the suction stroke.

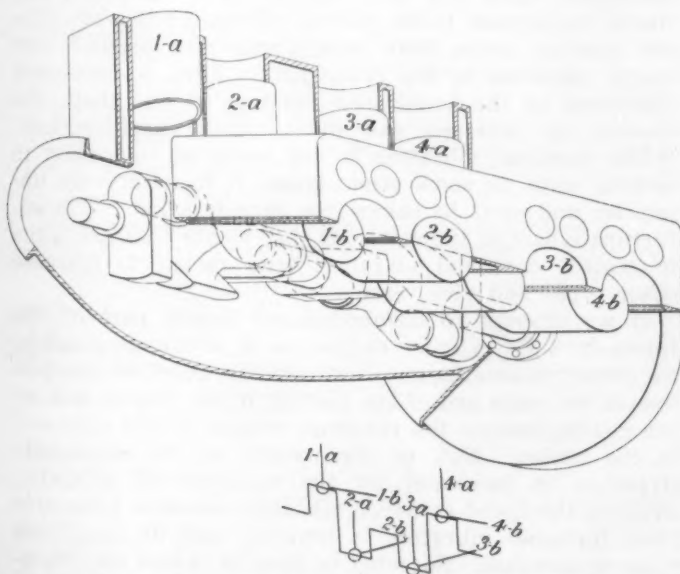


FIG. 8—EIGHT-CYLINDER BALANCED V-TYPE ENGINE
Displacement, 300 Cu. In.; Cylinders, 3.62 x 3.62 In.; Valve Port, 1 1/2 In. The Firing-Order for the Upper Drawing Is

Order of Cylinders
0 and 360 Deg. 90 and 450 Deg. 180 and 540 Deg. 270 and 630 Deg.
1a and 2b 1b and 3a 4a and 3b 2a and 4b
1a-1b-4a-4b-2b-3a-3b-2a
1a-3a-3b-2a-2b-1b-4a-4b
1a-3a-4a-2a-2b-1b-3b-4b

The Firing-Order for the Lower Drawing Is

Order of Cylinders
0 and 360 Deg. 90 and 450 Deg. 180 and 540 Deg. 270 and 630 Deg.
1a and 4a 1b and 4b 2a and 3a 2b and 3b
1a-4b-3a-2b-4a-1b-2a-3b
1a-4b-2a-3b-4a-1b-3a-2b
1a-1b-3a-3b-4a-4b-2a-2b
1a-1b-2a-2b-4a-4b-3a-3b

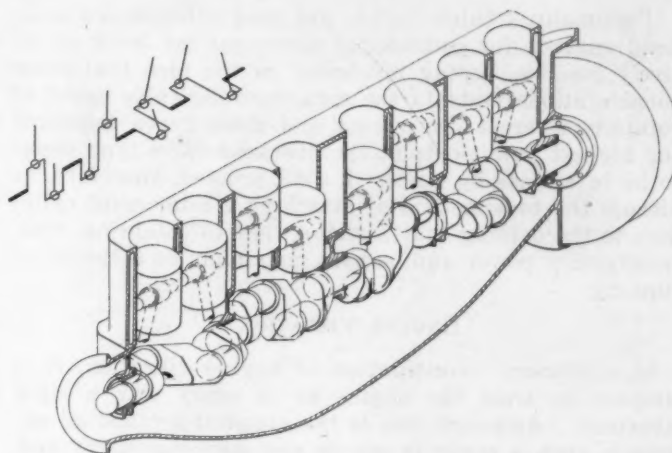


FIG. 9—EIGHT-CYLINDER-IN-LINE FIVE-BEARING ENGINE
Displacement, 300 Cu. In.; Cylinders, 3.62 x 3.62 In.; Valve Port, 1 1/2 In. The Firing-Order for the Drawing at the Left Is

Order of Cranks: 1 and 4, 6 and 7, 2 and 3, 5 and 8

1-6-3-5-4-7-2-8
1-6-2-5-4-7-3-8
1-6-3-8-4-7-2-5
1-6-2-8-4-7-3-5
1-7-3-5-4-6-2-8
1-7-2-5-4-6-3-8
1-7-3-8-4-6-2-5
1-7-2-8-4-6-3-5

The Firing-Order for the Drawing at the Right Is

Order of Cranks: 1 and 8, 4 and 5, 2 and 7, 3 and 6

1-5-2-6-8-4-7-3
1-4-7-6-8-5-2-3
1-4-2-3-8-5-7-6
1-4-2-6-8-5-7-3
1-5-7-6-8-4-2-3
1-5-7-3-8-4-2-6
1-5-2-3-8-4-7-6
1-4-7-3-8-5-2-6

On the basis of these figures it seems that, assuming the same rear-axle ratio and the same weight in both cases, the multi-cylinder engine would give the same hill-climbing ability and a much higher maximum-speed than the single-cylinder engine. When it comes to weight and cost, however, it is pretty certain that a single-cylinder engine of 300-cu. in. displacement would weigh less and cost less than 12 single-cylinder engines, each of 25-cu. in. displacement. On the other hand, it would be necessary to use considerably more than 300 cu. in. in a single-cylinder engine to obtain the same maximum horsepower that could easily be obtained in the 12 smaller engines.

Admitting then that a multi-cylinder engine has such very obvious advantages, how many cylinders should we use and what is the best way to couple these cylinders to the driving-shaft to obtain the desired result? The method of coupling the cylinders to the driving-shaft has a very important effect on the smoothness of running of the engine and also on the maximum power obtainable from the cylinders themselves.

TYPES OF CYLINDER CONSTRUCTION

In cylinder design, we have pretty well standardized on two types at present, largely because of their detonation characteristics. One of these is the valve-in-head, the other the L-head, although a type using one valve in the head and one on the side per cylinder is still in commercial use. In practically all L-head and in-line engines having more than four cylinders, the design of the valves, ports and cooling system is distinctly cramped, unless the cylinder spacing is made greater than is required by other considerations. The T-head engine, with its many mechanical advantages in layout, has been completely removed from the picture because of the extremely bad shape of the combustion-chamber.

Personally, I think that to get good valve-design in L-head engines for commercial passenger-car work is entirely possible, basing my belief on the idea that other considerations restrain the maximum desirable speed of rotation, whereas, for racing and other types requiring the highest power-output, the overhead-valve type seems to be in a class by itself. I shall proceed, therefore, to discuss the best method of attaching a number of cylinders to the driving-shaft, with a view to obtaining, first, satisfactory power and, second, maximum smoothness of running.

ENGINE VIBRATION

In a primary investigation of engine vibration, it is simplest to treat the engine as in every way a rigid structure. Although this is the simplest method of approach, such a study is not in any way conclusive and, as I will show later, often leads to serious mistakes. If the position of the center of gravity of an engine, including all its moving parts, remained stationary during operation, naturally no exterior vibration would be apparent, except such as might be due to variations in the turning-moment or torque reaction consequent on this method of producing power. Furthermore, if the position of the center of gravity is translated at a low enough speed, the result is not noticeable. In other words, if the various parts moving round inside the engine as a whole move in such a way with relation to each other that the exact center of gravity of the whole mass never departs from one position, naturally no external forces would be produced by the operation of the engine. The single-cylinder engine is the most obvious case in which one piston rises and falls.

Considering the piston alone, a very decided change takes place in the position of the center of gravity. The big end of the connecting-rod, the crankpin and such parts, of course, can be balanced by opposing weights on the crank-arms, and their rotation will produce no change in the position of the center of gravity; but no weight that can be applied, which rotates with the crankshaft at crankshaft speed, can take care of the variations in piston position. At the speed of hand-cranking, the vibration of a single-cylinder engine would not be noticeable, because of anything that happens in the engine itself, although the lifting of the front end of the car by the person cranking would possibly be very noticeable. Probably, in a very slow-running single-cylinder engine, the torque reaction-vibration would be far more noticeable under full load than the actual mechanical free-vibration.

STABILITY OF THE CENTER OF GRAVITY

Stability of the position of the center of gravity in designs of multi-cylinder engines can be obtained in many ways. The radial-type engine, shown in Fig. 4, consists of an odd number of cylinders, three, five, seven, or nine, equally spaced around a single crank-throw. In such an engine, if all the connecting-rods could be connected to the crankpin so as to meet at the crankpin center, we should have the desired result. The reason is that the pistons and other parts, when taken together, have a center of gravity that moves in a circle and can therefore be balanced by appropriate balancing-weights on the crankshaft. Due to the fact that no connecting-rod construction suitable for high-speed operation has ever been developed that allows attachment to be made in this way, that condition is not entirely met. What is used is a single master-rod and articulated rods attached to

it by wristpins. With this arrangement, especially if the connecting-rods are short, the pistons move through a slightly warped circle, and a certain amount of free vibration is therefore noticed. This is the only type of engine in commercial use, however, in which the movements of the individual centers of gravity of the engine parts take place in the same transverse plane. In practically all others, the balancing planes are more or less separated. That is one of the most important considerations that I wish to emphasize, and it is one that has been frequently overlooked. When this is the case, unless the structure is perfectly rigid, which is of course impossible, other types of vibration are produced, which, under certain conditions, can and do become even more unpleasant than ordinary free vibration.

BALANCE OF THE SIX-CYLINDER ENGINE

The six-cylinder engine, in its simpler forms, is a notable example of this type of balancing. Obviously, a long engine, in which the end cylinders are balanced against the central cylinders, is subject to this difficulty in a marked degree. In the six-cylinder type, as almost universally laid out, the two central cylinders operate together; the two end ones, No. 1 and No. 6, operate together; and the two intermediates operate together. Thus, a very heavy weight is always moving in the center and is balanced by the operation of two weights that are separated by distances that vary, due to the size of the engine, from 5 or 6 in. to perhaps 1 ft. or more. So long as the speeds are moderate, and the forces produced by the rotation of the engine and the acceleration and deceleration of the moving weights are therefore low, nothing happens. When the speed increases, however, the crankcase springs under the increasing loads so that vibrations are produced directly in the crankcase which are very serious in amount and distinctly unpleasant to the driver. Certain types of cylinder hook-up, more than others, can also produce torsional vibration in the crankshaft. That is dependent somewhat on the length and the type of the shaft, the number of bearings and many other considerations. While torsional vibration is not really so important in certain ways as some other types, it is deservedly unpopular and must be taken into consideration. The unfortunate part of the matter is that means that are taken to remedy torsional vibration tend rather to increase other types and vice versa.

If we attempt to counterbalance locally part of the forces in a six-cylinder engine, as is obviously possible, we cannot counterbalance entirely the effect of the pistons at the ends and of the pistons in the center, but we can counterbalance the rotating weights at the ends and in the center. But, as the weight of the crankshaft structure is increased by the addition of balancing weights, the speed at which vibration becomes noticeable from torsional vibration is lowered, and its amplitude tends to increase. So, what is done to reduce the vibration of the engine structure by springing makes it more difficult to take care of another type of vibration. On the other hand, if the crankshaft is made larger all the way through, including the wristpins, to cut down the effect of torsional vibration by raising its period and reducing the amplitude, the weight of the revolving parts, especially the big end of the connecting-rod, is increased, and the maximum speed at which the engine can properly be run is reduced. At the same time, the forces that tend to throw the crankcase out of line are increased and produce vibration.

TORQUE REACTION

I have mentioned torque reaction as a source of vibration. This is relatively unimportant in engines having six cylinders or more, except that, at certain speeds, it seems to emphasize other types of vibration. It is very noticeable that the vibration in four-cylinder engines seems to be greater while the engine is overrunning at high speed than while the power is being applied. A surprising variation in torque reaction, in engines of the same size and the same number of cylinders, is produced by variations in the type of explosion. This is usually spoken of as roughness and is worthy of intensive research. When the throttle is wide open, this roughness sometimes appears in a shuddering feeling and is often accompanied by distinct bumping. Any action of this kind, of course, becomes less noticeable as the number of cylinders is increased.

In recent years the attempt to operate at higher and higher compressions has brought this latter consideration very much to the front. The higher the compression, other things being equal, the higher the peak of the indicator-card and the greater the tendency to roughness from that source.

The tendency toward higher compression so far, I think, has been caused more by a desire for higher speed and higher maximum engine-power than for gasoline economy. The most noticeable thing on the power-curve obtained by raising the compression of an engine is that a very much higher peak is produced at a somewhat higher speed. It increases the power very noticeably at the maximum point. The peculiar thing about roughness is that it is not completely dependent on the compression ratio. The shape of the cylinder-head in designs of L-head engines has considerable to do with it. Certain types of head—and these are frequently, if not always, heads in which the turbulence is at a maximum—

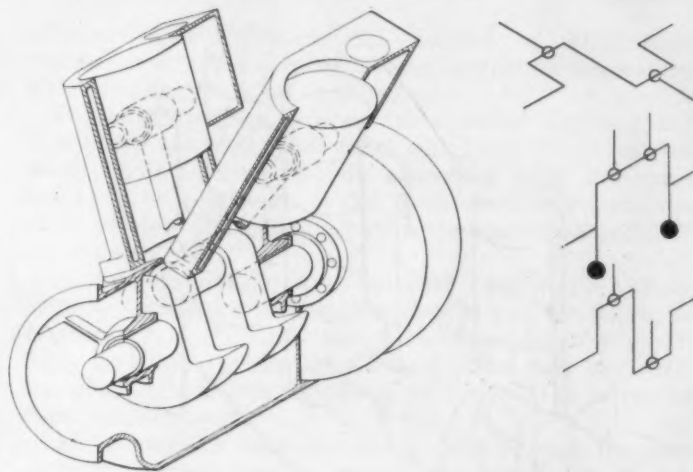


FIG. 11—TWO-CYLINDER 45-DEG. ENGINE
Displacement, 300 Cu. In.; Cylinders, $5\frac{1}{4} \times 5\frac{1}{4}$ In.; Valve Port, $2\frac{1}{4}$ In.
In the Diagrammatic Sketches at the Right, the Upper One Is That of a Two-Cylinder-Opposed Engine; the Central One, That of the Old Peerless Type in Which Both Cylinders Worked Together on the Same Long Crankpin; the Bottom One, That of a Vertical Engine Having the Cylinders in Pairs and the Crankpins Spaced 180 Deg. Apart

produce very rough-running engines. Another head with practically the same or even higher compression, with as much or more power, may produce a much more smoothly running engine, from the general feel of the engine. It is hard to describe, if you have not been working with it, but what we call roughness is a very noticeable quality.

QUALITY OF FUEL MIXTURE

Another thing that affects it is the quality of the fuel mixture. Apparently, the more complete the mixture is, by proper vaporization in the manifold, proper amount of heat and similar considerations, the more smoothly the engine will operate. I do not mean by this that the distribution may be bad. An engine may operate with each cylinder apparently doing its fair share of the work, so far as may be indicated by the feeling, yet the general effect is rough. Another one might feel much smoother, although two of the cylinders might be suffering from rather bad distribution that could be felt.

To illustrate various features discussed in this paper, I have prepared schematic drawings of a considerable number of types of engine having from one to nine cylinders. I have omitted the 12-cylinder V-type engine, because it is not used in commercial motor-cars at the present time, and because its characteristics are almost identical with those of the six-cylinder engine. In view of the importance of the six-cylinder engine at present, I have shown it with three different crankshaft arrangements, one with three bearings being illustrated in Fig. 5, one with four bearings in Fig. 6, and one with seven bearings in Fig. 7. The eight-cylinder engine is also shown in several different styles, including one having double-opposed cylinders, Fig. 8, that has some extremely interesting possibilities, and an eight-cylinder-in-line five-bearing engine, Fig. 9. The nine-cylinder radial engine, shown in Fig. 4, can be referred to for purposes of comparison. None of the drawings or figures are intended to be more than comparative.

BASES OF COMPARISON OF ENGINES

We have attempted to proportion all the various types alike as nearly as possible and have used the same materials for the various parts, an exception being that some consideration for foundry practice has been shown

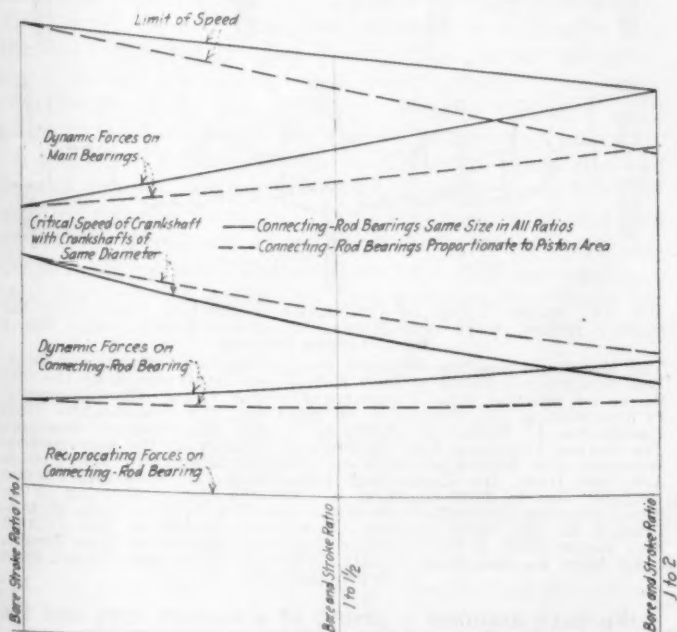


FIG. 10—COMPARISON OF THE CONNECTING-ROD BEARINGS OF SIX-CYLINDER ENGINES OF 300-CU. IN. DISPLACEMENT FOR DIFFERENT RATIOS OF BORE AND STROKE

In One Curve of Each Pair the Connecting-Rod Bearings Are the Same Size in All Ratios; in the Other They Are Proportional to the Area of the Piston. The Piston Weights Are Somewhat Heavier in Proportion on the Smaller Sizes Due to Limits of Manufacture. All the Dynamic Forces Are Comparative Only. The Limit of Speed Is Based on the Speed at Which the Dynamic Force on the Connecting-Rod Bearing Equals 1000 Lb. per Sq. In. The Critical Speed of the Crankshaft Is Inversely Proportional to the Square Root of the Length, the Diameter Being the Same in All Cases. All Calculations Are Based on Cast-Iron Pistons and Steel Connecting-Rods

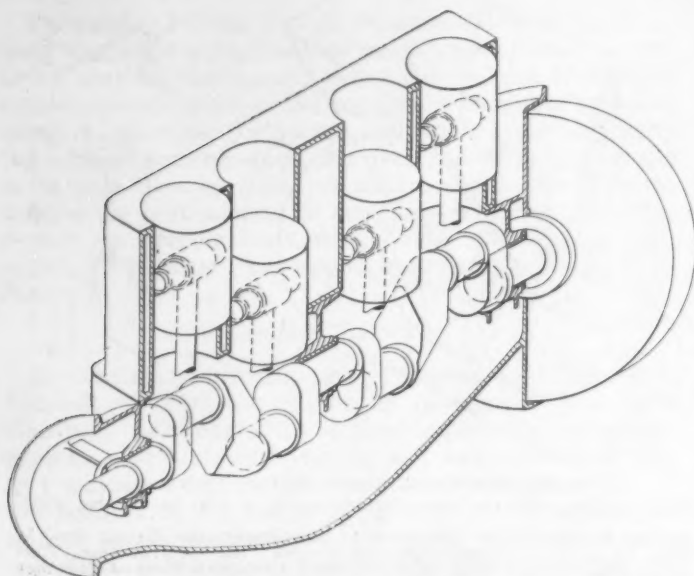


FIG. 12—CONVENTIONAL FOUR-CYLINDER ENGINE IN WHICH THE CRANKS ARE TWO AND TWO, 180 DEG. APART
Displacement, 300 Cu. In.; Cylinders, 4.57 x 4.57 In.; Valve Port, 1 3/4 In. The Firing-Order Is 1-3-4-2, 1-2-4-3

in the dimensions of the smaller pistons. That any comparisons can be badly upset by changing the weights of the moving masses by using different materials in the pistons or the connecting-rods should be obvious. It should also be apparent that there are probably some general sizes of engine, cylinder and piston in which the desirable thickness of the material, for foundry reasons, is approximately the same as that required for mechanical strength or rigidity. Cylinders made much smaller than the optimum size inevitably weigh more per cubic inch of displacement. Proper crankshaft-design is probably the most important feature of any multi-cylinder engine. In many cases in the past the performance of a particular make of engine has been limited by a certain bearing's being under size, or by undue vibration

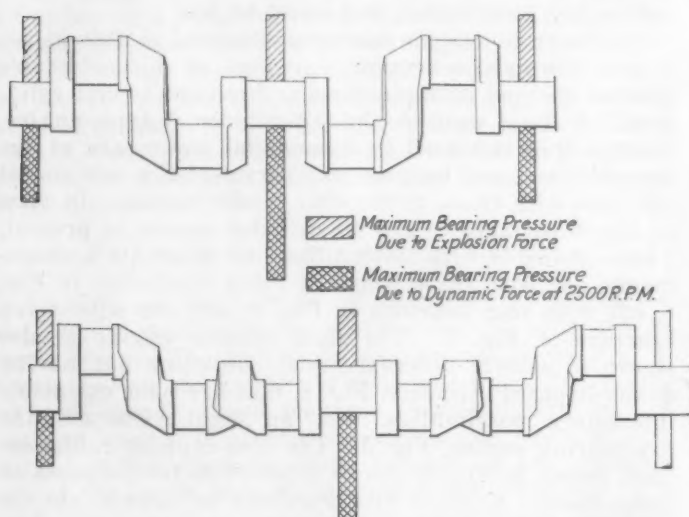


FIG. 13—MAXIMUM BEARING-PRESSURES ON THE THREE-BEARING CRANKSHAFTS OF FOUR (ABOVE) AND (BELOW) SIX-CYLINDER ENGINES

The Maximum Bearing-Pressure Due to the Explosion Force and That Due to Dynamic Force at 2500 R.P.M. Are Represented by the Two Series of Blocks. In Calculating the Pressures on the Bearings, the Crankshafts Were Considered to Have No Stiffness at the Intermediate Bearings. The Actual Pressure Will Be Slightly Greater on the Intermediate Bearings and Somewhat Less on the End Bearings. The Pistons Are Cast Iron; the Connecting-Rods, Steel

caused by a flimsy badly supported shaft. The central bearing on four-cylinder engines, and even on some sixes, has been a notable case in point.

What I have tried to do in the drawings is to bring out some of the limiting qualities of different cylinder and crankshaft arrangements. When we undertook to work up the data for them I did not know absolutely what they would show. For purposes of comparison, certain assumptions or ground rules for all the engines must, obviously, be made. We have therefore assumed that they have cast-iron pistons, steel connecting-rods and, in practically all the engines shown, approximately equal bore and stroke ratios.

EFFECT OF CHANGING BORE AND STROKE RATIOS

The drawing shown in Fig. 10 indicates clearly that we should not get a very different result if we used a wide range of bore and stroke ratios; that is, granting the other assumptions that we have made merely for purposes of study, we should be about as well off if a 1 to 1 ratio were used as we should be with any other.

Maximum Bearing Pressure Due to Explosion Force
Maximum Bearing Pressure Due to Dynamic Force at 2500 R.P.M.

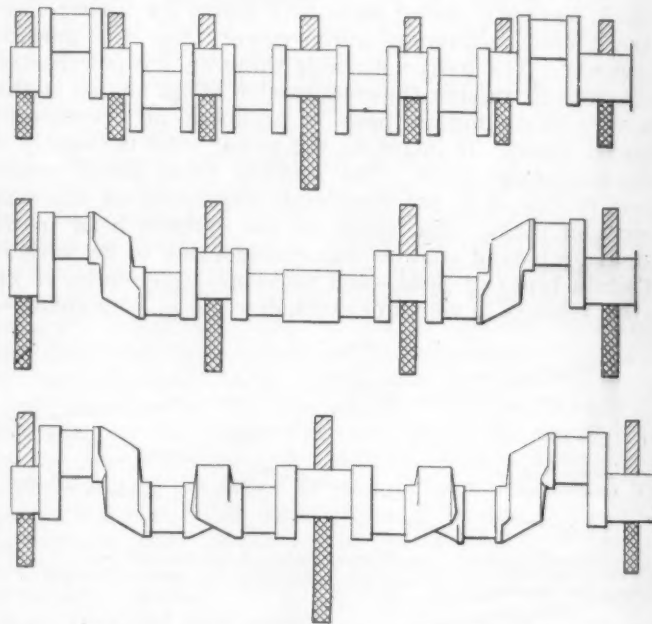


FIG. 14—THREE TYPES OF CRANKSHAFT, HAVING (FROM THE TOP DOWN) SEVEN, FOUR AND THREE BEARINGS RESPECTIVELY FOR A SIX-CYLINDER ENGINE

The Maximum Bearing-Pressure Due to Explosion Force and Those Due to Dynamic Force at 2500 R.P.M. Are Represented by the Two Series of Blocks. The Pressures Do Not Occur Simultaneously. In Calculating the Pressures on Bearings, the Crankshafts Were Considered to Have No Stiffness at the Intermediate Bearings. The Actual Pressures Will Be Slightly Greater on the Intermediate Bearings and Somewhat Less on the End Bearings. The Pistons Are Cast Iron; the Connecting-Rods, Steel. An Interesting Point Brought Out in This Drawing Is That the Center Bearing of the Seven-Bearing Crankshaft Shown at the Top Is Nearly as Heavily Loaded as the Three-Bearing Crankshaft Shown at the Bottom. This Means That If Six-Cylinder Engines Are Run at High Speeds, They Must Be Balanced Locally, Whether They Have Three, Four or Seven Bearings

We have assumed a piston of a certain type and the same proportion in all engines, that is, the skirt portion of the piston in all cases is equal to the bore. For computing loads on bearings, we have adopted 2500 r.p.m. as the speed for determining loads due to moving forces, and 300 lb. per sq. in. as the maximum pressure due to explosion forces.

I have already discussed the single-cylinder engine. It is interesting simply as being the most obvious case of an engine out of balance due to bad free forces, al-

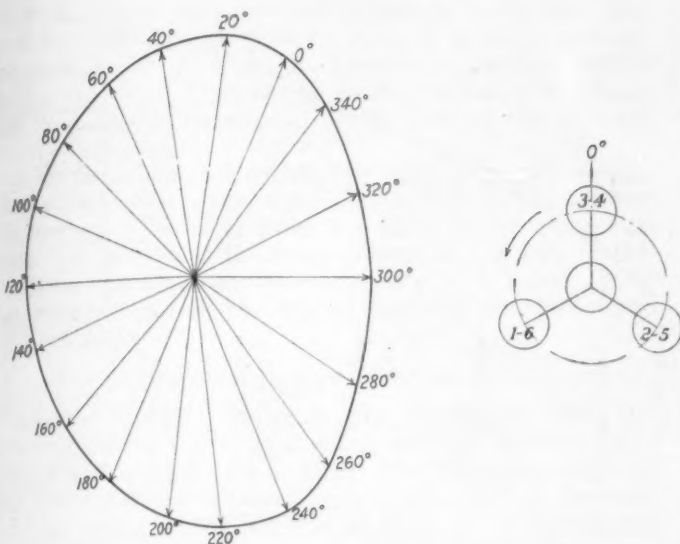


FIG. 15—TOTAL DYNAMIC PRESSURE ON THE CENTER BEARING OF A THREE-BEARING SIX-CYLINDER ENGINE AT DIFFERENT PARTS OF THE REVOLUTION

The Maximum Dynamic Pressure Is Vertical. The Curve Showing the Magnitude and Direction of the Forces at Different Points Is More or Less Elliptical in Form

though in other ways it is extremely good. Probably it would never suffer from torsional vibration. It is very rigid, due to being close coupled. The crankshaft is short and, under those conditions, to make the crankcase rigid is easy.

THE TWO-CYLINDER-OPPOSED ENGINE

The two-cylinder-opposed engine is only one of many two-cylinder types. The diagrammatic sketch shown at the upper right of Fig. 11 is a two-cylinder-opposed engine, in which, of course, the cylinders are opposite and the two crankpins 180 deg. apart. The pistons therefore move in and out oppositely to each other. If it were possible to make the cylinders directly opposite each other, the engine would be practically perfectly balanced. On account of having crankpin bearings of some size and equally spaced, because the offset connecting-rod has frequently refused to work in the way the designers had wished it would work, we must separate the cylinder centers somewhat. That results in a rocking couple, a tendency for the engine to rock horizontally, which in-

roduces some vibration, the amount of which and whether it is unpleasant depending largely on the way in which the engine is set in the chassis.

The most common type of two-cylinder engine today is probably the motorcycle twin, which is a V-type engine having both connecting-rods connected with the same crankpin. This design is far from attractive from the point of view of balancing but in the sizes used is fairly satisfactory.

In the old Peerless two-cylinder car of 1903, both cylinders worked together on the same long crankpin, as is shown in the central sketch at the right of Fig. 11. This type has equally spaced explosions, but obviously has considerable free vibration, especially if it is run at high speeds.

An attempt to overcome this vibration was the two-cylinder vertical engine, having the cylinders in pairs and the crankpins spaced 180 deg. apart, shown in the bottom sketch at the right of Fig. 11. This engine has a bad rocking-couple that makes vibration fully as unpleasant as the type having the two cylinders working together shown in the middle sketch.

I have no drawing of the three-cylinder engine that was actually used commercially. That engine is exactly the same as one-half of a six-cylinder engine, the three cranks being spaced 120 deg. apart. The fact that the pistons are spaced along the crankshaft prevents it from being perfectly balanced.

Fig. 12 shows a conventional four-cylinder engine in which the cranks are two and two, 180 deg. apart. As I have said, this engine is in larger use than any other type today, thanks to Mr. Ford and the able assistance of the Chevrolet Company. In many ways it is a very satisfactory engine, if it is not run too fast. The old Simplex four-cylinder engine having a gear ratio of about 2.25 or 2.50 to 1.00 was a very pleasant car to drive at high speed. In fact, at 50 m.p.h. I think that many persons would prefer it today to many modern cars with their high-speed engines, even though they may have six or eight cylinders.

EFFECT OF DISPOSITION OF CYLINDERS LENGTHWISE

From this point on, I shall emphasize the effect of the disposition of cylinders lengthwise of the engine in causing vibration. The four-cylinder engine has suffered probably more than any other from inadequate center bearings. Many cars today are limited as to the time between overhauls by the center bearing, and in

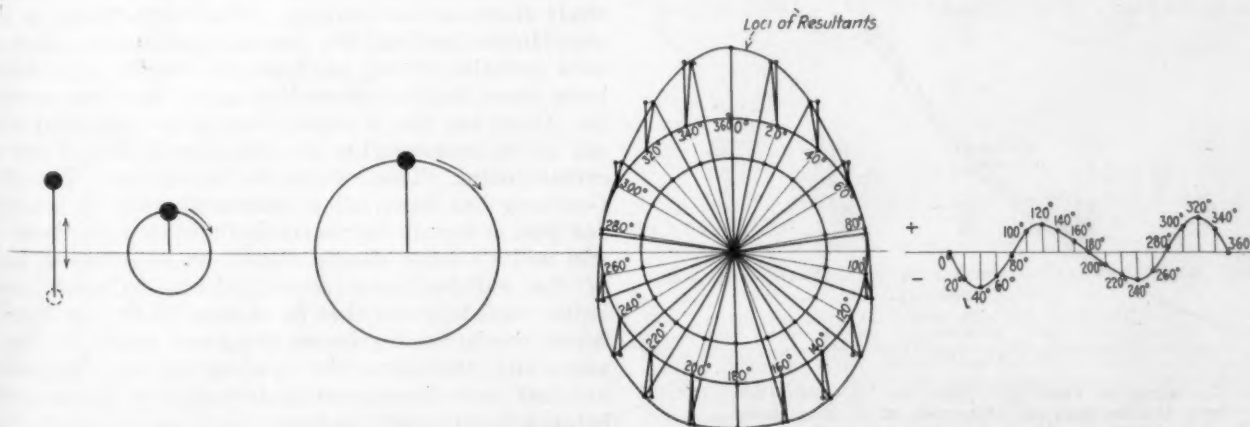


FIG. 16—DIVISION OF THE DYNAMIC FORCES ON THE CRANKPIN OF A SINGLE-CYLINDER ENGINE

The Three Drawings at the Left Show the Straight Reciprocating Force, the Reciprocating Force of the Big End of the Connecting-Rod and the Reciprocating Force of the Crankpin and the Crank-Arms Connected to That Crank Respectively. In the Next Drawing to the Right Is Shown the Resultant of These Three Forces, Indicating Clearly Why Lateral Rigidity Is Necessary in the Crankcase, If Local Counterbalancing Is Not Fairly Complete. The Rotative Effect of the Reciprocating Force Is Shown in the Diagram at the Extreme Right

many more the maximum allowable engine-speed has been fixed by the center bearing.

The upper drawing of Fig. 13 is a three-bearing crankshaft for a four-cylinder engine, drawn in the conventional way. The bands above the shaft represent the comparative maximum explosion-pressures produced on the bearings at any time. They are not produced at the same time, of course, but in each case the pressure is the maximum that can be produced on that bearing by an explosive force. The bands below the shaft represent the maximum dynamic pressures produced on the bearings at 2500 r.p.m. It is plain why the center bearing has been a limiting feature in four-cylinder engines, the dynamic load on that bearing at 2500 r.p.m. being more than twice the maximum explosion-pressure, while on the two end-bearings the dynamic pressure is nearly the same as the explosion pressure. It must always be borne in mind that this pressure, while its first result shows up in the repairman's hands, necessitating the changing of bearings because they are worn out, is pressing equally hard on the crankcase. Very few crankcases in four-cylinder engines can withstand this pressure without considerable distortion; and to distort the crankcase of an engine operating at high speed without the vibration produced by the distortion being transmitted to the car is not possible.

TYPES OF CRANKSHAFT FOR SIX-CYLINDER ENGINE

Three types of crankshaft for six-cylinder engines having three, four and seven bearings, respectively, are shown in Fig. 14. Just below the shaft of the three-bearing four-cylinder engine shown in Fig. 13 is also shown that of the three-bearing six-cylinder engine, the characteristics of which are very similar to those of the former in that a very heavy dynamic load must be borne by the center bearing. The crankcase, however, is longer and frequently slimmer and, for that reason, is apt to be less rigid and more likely to produce vibration.

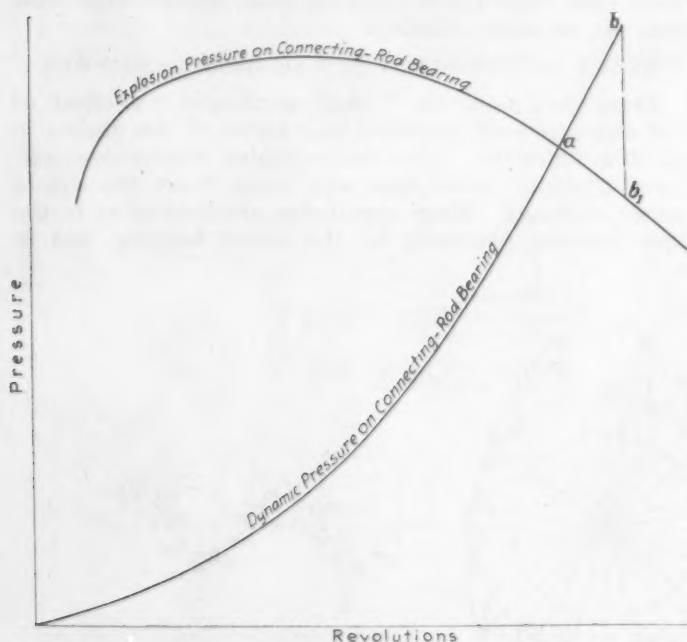


FIG. 17—VARIATION OF THE EXPLOSION AND DYNAMIC PRESSURES ON THE CONNECTING-ROD BEARING WITH THE SPEED

The Curve of the Explosion Pressure Is Shown at the Top; That of the Dynamic Pressure Below. As the Speed Increases, the Explosion Pressure Drops Off Very Fast, While the Dynamic Pressure Increases Very Fast. The Calculations Are Based on a Six-Cylinder Engine of 300-Cu. In. Displacement Having Cast-Iron Pistons and Steel Connecting-Rods. The Minimum Explosion-Pressure Is 300 Lb. per Sq. In.

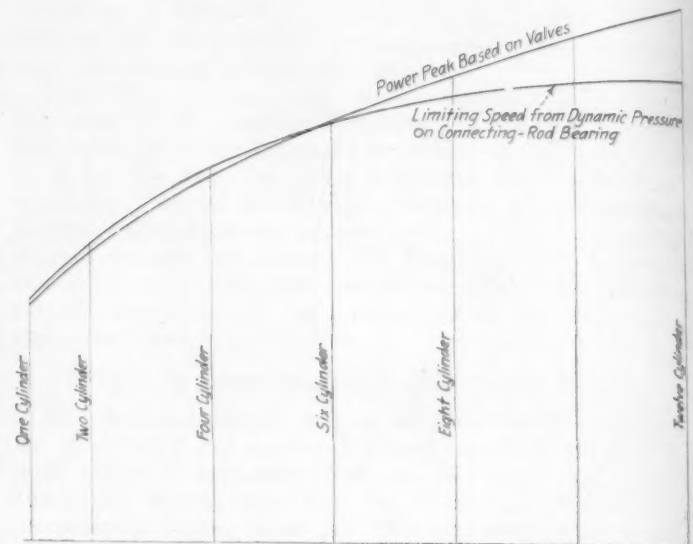


FIG. 18—CURVE OF THE LIMITING SPEED DUE TO THE DYNAMIC PRESSURE ON THE CONNECTING-ROD BEARING OF ENGINES HAVING THE SAME TOTAL DISPLACEMENT BUT VARYING NUMBERS OF CYLINDERS. The Piston Weights Are Somewhat Heavier in Proportion on the Smaller Sizes. The Dynamic Forces Are Comparative Only. The Limit of the Speed Is Based on the Speed at Which the Dynamic Force on the Connecting-Rod Bearing Equals 1000 Lb. per Sq. In. of Area. The Power Peak Is Based on the Speed at Which the Average Velocity through the Valve Equals 13,000 Ft. per Min. The Pistons Are Cast Iron; the Connecting-Rods, Steel. Under the Assumptions Made, the Curve Flattens Out at 12 Cylinders, Indicating that No Additional Increase of Speed Is To Be Expected from Further Increase of the Number of Cylinders

All the dynamic pressure is not vertical. The maximum dynamic pressure is vertical, but the total dynamic pressure at different parts of the revolution is shown on the drawing in Fig. 15. The dynamic pressure on a three-bearing six-cylinder engine is more or less elliptical. The common type of block-cast six-cylinder engine is extremely rigid vertically. Many of them, however, are split on the center line of the crankshaft, and the lower crankcase in such cases is usually a very light steel stamping. Obviously, therefore, such crankcases are far from rigid laterally. The result is that running such engines at high speed is likely to produce and does produce very considerable crankcase distortion and vibration, which is transmitted to the passengers in the car.

The interesting thing about the drawings reproduced in Fig. 14 is the fact that the center bearing on the seven-bearing crankshaft shown at the top is nearly as heavily loaded dynamically as it is on the three-bearing shaft shown at the bottom. What this means is that if six-cylinder engines are run at high speeds, they must, to a certain extent, be balanced locally, whether they have three, four or seven bearings. In other words, the No. 1 and the No. 6 cranks cannot be depended upon to act as balance-weights for No. 3 and No. 4 beyond a certain point. This, of course, is not new. The Hudson Company has been using counterweights in its engines for years; but it is clearly brought out in these views and will be more clearly shown as we proceed to some of the eight-cylinder types, which, naturally, are in better local balance; that is, in some of the eight-cylinder types, the balancing forces are more nearly in the same plane and, therefore, the local strains on the crankcase are less and the necessity for attempting to counterbalance them locally is less.

COUNTERBALANCING

Counterbalancing locally by counterweights almost inevitably increases the torsional-vibration effects to a

point at which they become extremely noticeable and probably will have to be taken care of by some form of damping device, such as the Lanchester damper, which is of a frictional type, or the Harmonic balancer, which has been applied to several of the cars of the General Motors Corporation.

A perfectly obvious answer to local counterbalancing, the balancer and a few other such things is, Do not run the engine so fast and make it a little larger. I do not know yet just what the final answer will be but, if the torsional vibration can come in only at a speed above the speed at which the engine can run, the passenger will not feel it.

DIVISION OF DYNAMIC FORCES

Another drawing, shown in Fig. 16, indicates how the dynamic forces would be divided, considering the crankpin of a single-cylinder engine. The three drawings at the left show the straight reciprocating force, the centrifugal force of the big end of the connecting-rod and the centrifugal force of the crankpin and the crank-arms connected to that crank, respectively. To the right is the resultant of these three forces, which shows clearly why lateral rigidity is necessary in a crankcase, if the local counterbalancing is not fairly complete. The rotational effect of reciprocating force is shown in the diagram at the extreme right.

Two drawings, shown in Figs. 17 and 18, I shall refer to briefly. In Fig. 17, one curve shows the variation of the dynamic pressure on the connecting-rod bearing with the speed; the other curve, the variation of the explosion pressure on the connecting-rod bearings with the speed. The shape of these curves is interesting; the amount is not. The fact is, that as the speed increases, the explosion pressure drops off extremely fast, while the dynamic pressure increases very fast. If the bearings have to be made excessively large to stand up under the dynamic pressure, much larger than would be required by the explosion pressure at that speed, this feature is an indication that the design is unbalanced; in other words, other things being equal, to get the most out of the material that is put into the engine, we might assume that the pressures ought to be those near a rather than out at bb_1 .

CURVES OF THE LIMITING SPEED

Fig. 18 simply shows the shape of two curves of the limiting speed, the lower one being the limiting speed from the dynamic pressure on the connecting-rod bearings of engines with varying numbers of cylinders having the same total displacement. With the assumptions that we have made, I will say that, at 12 cylinders, the curve is pretty well flattened out, indicating that, with those assumptions, nothing as regards the ability to increase the speed is evidently to be expected from increasing the number of cylinders, that is, always provided you wish to do it, which as yet I do not.

The next move in the program of vibration removal was the improvement of the eight-cylinder engine. It took two forms, the complete balancing of the V-type eight and the development of the straight-line eight. The upper drawing in Fig. 19 is a study of the balanced V-type eight, such as is used in the Cadillac. The dynamic forces on the main bearings are practically negligible. They are so much less than the explosion pressures that they mean little or nothing. The lower drawing in Fig. 19 is the old V-type Cadillac, which has practically the same characteristics as a four-cylinder engine, that is, a very heavy load on the central bearing.

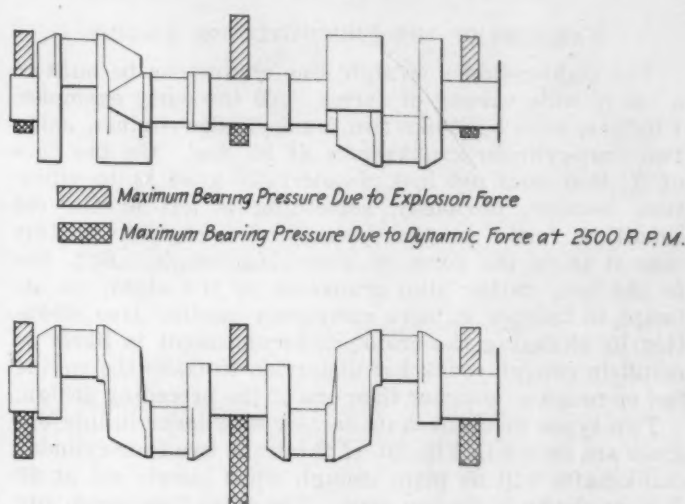


FIG. 19—CRANKSHAFTS FOR EIGHT-CYLINDER ENGINES
The Upper Drawing Shows a Three-Bearing Crankshaft with 90-Deg. Crank-Angle for a Balanced V-Type Eight, Such as Is Used in the Cadillac Car. The Lower Drawing Is a Three-Bearing Crankshaft with 180-Deg. Crank-Angle Used in the Old V-Type Cadillac. The Two Series of Blocks Represent the Maximum Bearing-Pressure Due to Explosion Force and That Due to Dynamic Force at 2500 R.P.M. Respectively. In Calculating the Pressure on the Bearings, the Crankshafts Were Considered To Have No Stiffness at the Intermediate Bearings. The Actual Pressures Will Be Slightly Greater on the Intermediate Bearings and Somewhat Less on the End Bearings. The Pistons Are Cast Iron; the Connecting-Rods, Steel

As a matter of fact, that was one of the limiting bearings in the old Cadillac engine.

Other limiting features that appear in this type of engine are due to the addition of counterweights and the torsional characteristics. The addition of counterweights made it desirable to stiffen the crankshaft, which was made larger in diameter, and this affected the maximum safe running speed and other characteristics of the crankpin bearing. It is the same old story: you cannot get something for nothing in any of these features.

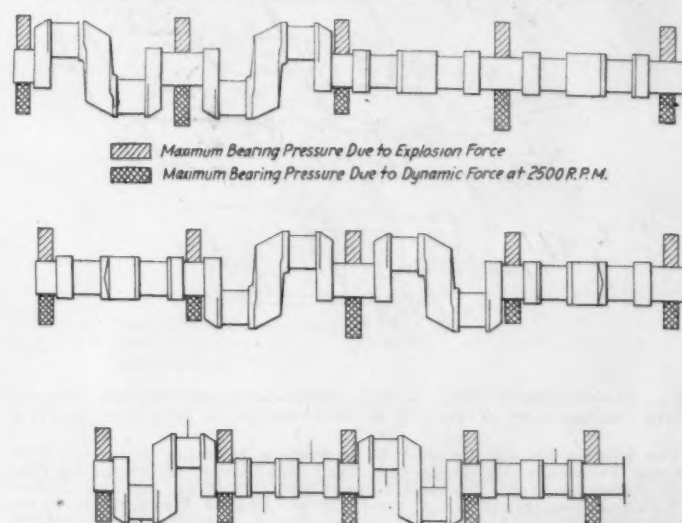


FIG. 20—TWO TYPES OF FIVE-BEARING CRANKSHAFT FOR EIGHT-CYLINDER ENGINES

The Upper and Central Views Are for Eight-Cylinder-in-Line Engines, the Upper Being the Double Four, the Central View, the More Completely Balanced Type. The Bottom View Is a Crankshaft Formed by Connecting Together Four Double-Opposed Pairs of Cylinders, Thus Obtaining the Advantages of Local Balancing and Having the Balancing Forces as Near Together as Possible. The Maximum Bearing-Pressure Due to Explosion Force and That Due to Dynamic Force at 2500 R.P.M. Are Represented by the Two Series of Blocks. The Pressures Do Not Occur Simultaneously. In Calculating the Pressures on the Bearings, the Crankshafts Were Considered To Have No Stiffness at the Intermediate Bearings. The Actual Pressures Will Be Slightly Greater on the Intermediate Bearings and Somewhat Less on the End Bearings. The Pistons Are Cast Iron; the Connecting-Rods, Steel

VARIETIES OF THE EIGHT-CYLINDER ENGINE

The eight-cylinder straight-line engine can be built in a fairly wide variety of forms. All the early examples, I believe, were built like two four-cylinder engines, using two four-cylinder crankshafts at 90 deg. On the face of it, that does not look wonderfully good as to vibration, because, obviously, something is left of the old condition found in the four-cylinder engine; in this case it is in the form of a rocking couple. But, due to the long rather slim crankcase of the eight, an attempt to balance it more completely against free vibration by changing the crankpin arrangement is likely to result in enough crankcase distortion to make the engine feel as rough or rougher than one of the preceding design.

Two types of crankshaft for eight-cylinder-in-line engines are shown in Fig. 20. I think the two four-cylinder crankshafts will be plain enough when simply set at 90 deg., as shown in the top view. The other type commonly used, shown in the central view, is laid out very much like a four or a six, working from the center out and encounters somewhat the same difficulty as the six in preventing distortion.

The two crankshafts are the eight-cylinder type, that shown at the top being the double-four, and that in the center the more completely balanced type. The latter, due to having the two center-pins together, has a fairly heavy load on the center bearing. Even then the load on the center bearing is considerably less than that of a

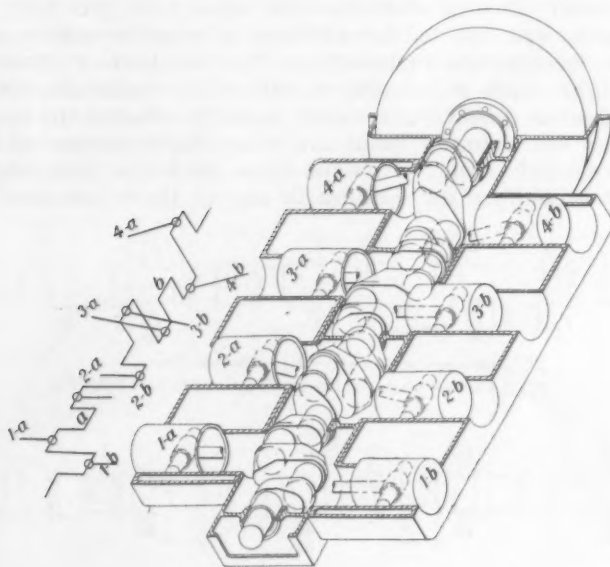


FIG. 21—COMPLETE VIEW OF THE EIGHT-CYLINDER-OPPOSED ENGINE, THE CRANKSHAFT OF WHICH IS ILLUSTRATED IN THE BOTTOM VIEW OF FIG. 20

The Engine Should Be in Nearly Perfect Running Balance. The Local Pressures All Along the Shaft are About as Slight as Can Be Expected in an Engine Having Eight Cylinders, and the Engine Would Be as Short as a Six-Cylinder Engine Having the Same Displacement. At the Left is Shown a Sketch of a Possible Arrangement of the Crankshaft in Which the Dynamic Pressures on the *a* and *b* Bearings are 40-Per Cent Greater Than Those on the Same Bearings of the Engine Illustrated in the Other Drawing. The Firing-Order of the Engine in the Smaller Drawing is

Order of Cylinders	0 and 360 Deg.	90 and 450 Deg.	180 and 540 Deg.	270 and 630 Deg.
	1a and 1b	2a and 2b	3a and 3b	4a and 4b
		1a-2b-3a-4b-1b-2a-3b-4a		
		1a-2a-3a-4a-1b-2b-3b-4b		
		1a-2a-3b-4b-1b-2b-3a-4a		

The Firing-Order of the Engine in the Larger Drawing is

Order of Cylinders	0 and 360 Deg.	90 and 450 Deg.	180 and 540 Deg.	270 and 630 Deg.
	1a and 1b	2a and 2b	3a and 3b	4a and 4b
		1a-3b-2b-4a-1b-3a-2a-4b		
		1a-3b-2a-4b-1b-3a-2b-4a		
		1a-3a-2a-4a-1b-3b-2b-4b		

six of equal length and distinctly less than that on the center bearing of a 90-deg. V-type eight. As the crankcase of a straight eight is much longer, however, it is probable that the amount of distortion, as compared with that of the V-type engine, would be greater even with the lessened pressure.

Both these types are reasonably well balanced with regard to the two types of load on the various bearings, that with the two four-cylinder shafts being slightly the better of the two.

FOUR DOUBLE-OPPOSED PAIRS

I dislike to take up a subject like this without inventing something, so being intrigued by the apparent advantages of local balancing, of having the balancing weights as near together as possible and by the beauties of the double-opposed engine, I connected four of the double-opposed pairs together. It certainly is a very pretty looking engine in many ways. This layout is shown at the bottom of Fig. 20. A complete view of the engine is shown in Fig. 21. The engine should be in nearly perfect running-balance. The local pressures all along the crankshaft are about as slight as can be expected in an engine having eight cylinders. The engine also would be about as short as a six having the same displacement; and, if we could run the frame of a motor-car through the cylinders, or do something of that sort, we could use it to great advantage. Seriously, if an attempt is made to get very high-speed engines, I think it is worth considering. I convinced myself very quickly by this course of drawing why the eight-cylinder engine is nearly universal today for racing. It might not be so, if we had much greater horsepowers but, with the limitation on displacement, which is a highly artificial way of rating racing-cars anyway, and does not mean much to the engineer, obviously we must go to the limit on turning the engines up to high speed. Everything in the drawings indicates that the eight-cylinder type is the easiest one with which to do it, and practice on the track indicates the same thing. On the drawing shown in Fig. 22, I have combined the various pressures shown on the several drawings.

CAUSES OF NOISY ENGINES

We could continue a study of this kind indefinitely and probably to some advantage, but I should like to speak about engine quietness. In the first place, engine noise, like every other noise, comes from vibration. Noise is nothing but vibration of the ear-drums. If our ear-drums do not vibrate, there is perfect silence, so far as we are concerned. That is worth considering, because the right kind of body design will probably produce a more quiet engine than anything that can be done to the engine.

As a matter of fact, most engines at fairly high speed are pretty noisy. It is inevitable that they should be. The rapid churning of a quantity of air, the sucking of air into the carbureter, all the little things that take place will certainly produce noise. If the engine vibrates at all, it sets up air waves, and they produce noise. If the frame of the car vibrates, or the tinware vibrates, due to engine vibration, noise is produced. These things must be taken care of in their own way, but a nice steady smooth purring noise is a wonderful thing to cover up many other noises that cannot be stopped.

In the poppet-valve engine, a frequent and common source of difficulty is the valves. The greater part of the noise is due to the valve's seating itself. The pick-

up relatively is much less. Long-continued experience indicates that, if the valve seats at a reasonable speed, the noise is not bad, always provided that the valve seats squarely. The worst trouble with poppet valves that I have seen is to get the valves to seat squarely, to have both the stem of the valve at right angles to the head of the valve and the guide at right angles to the seat. If that is the case, the valve can be let down slowly enough so that, at slower speeds, it will be quiet; and, at the higher speeds, they all sound pretty much the same.

OVERCOMING THE EFFECT OF HEAT ON THE VALVES

Now, the quieting process would not be so difficult, if we were dealing with a uniform temperature and, therefore, uniform engine-dimensions; but we are not. The inlet and exhaust-valves in an L-head engine are subjected to entirely different conditions of heat, and they respond accordingly. In many engines, the exhaust-valve stem will expand 0.009 or 0.010 in. when the engine is under a really heavy load. The inlet-valve stem, under those conditions, may remain constant in length, or may even shorten relatively to the cylinder, because of course the cylinder tends to lengthen.

The only way to overcome this difficulty is by providing what we call ramps. Very many ramps have been tried. Some optimistic engineers attempt to pick the lifter up, bring it into contact with the valve-stem at zero velocity and then go on from there. It has always seemed to me that this requires more accurate adjustment than anything we have ever tried before. I think the really safe thing to do is to produce a ramp that will give constant velocity over a number of degrees at the same engine-speed.

The curve reproduced in Fig. 23 shows how this works out. The dotted line is the entering curve of a certain type of lifter on a tangent cam. We found that with such an arrangement, if the stem and lifter had about

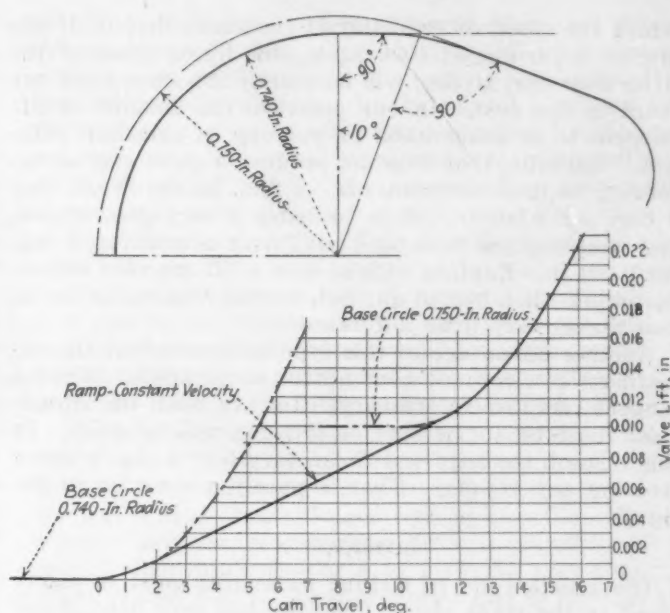


FIG. 23—CURVE SHOWING RELATION OF VALVE LIFT TO A RAMP GIVING CONSTANT VELOCITY OVER A NUMBER OF DEGREES AT THE SAME ENGINE-SPEED

The Dotted Line Is the Entering Curve of a Certain Type of Lifter on a Tangent Cam. If the Stem and the Lifter Have About 0.002-In. Clearance, They Are Reasonably Quiet. If a Tangent Is Taken at This Point on the Lift Curve and Is Continued for About 0.01 In. More, a Period of 10 Deg. in the Cam Motion Is Found During Which the Speed of the Lifter Is Constant

0.002-in. clearance, they were reasonably quiet. We therefore took a tangent at the 0.002-in. point on the lift curve, ran on for what was considered to be the right amount, that is, about 0.010 in. more, and then took up the curve from that point. When this has been done, a period of 10 deg. in the cam motion was found during

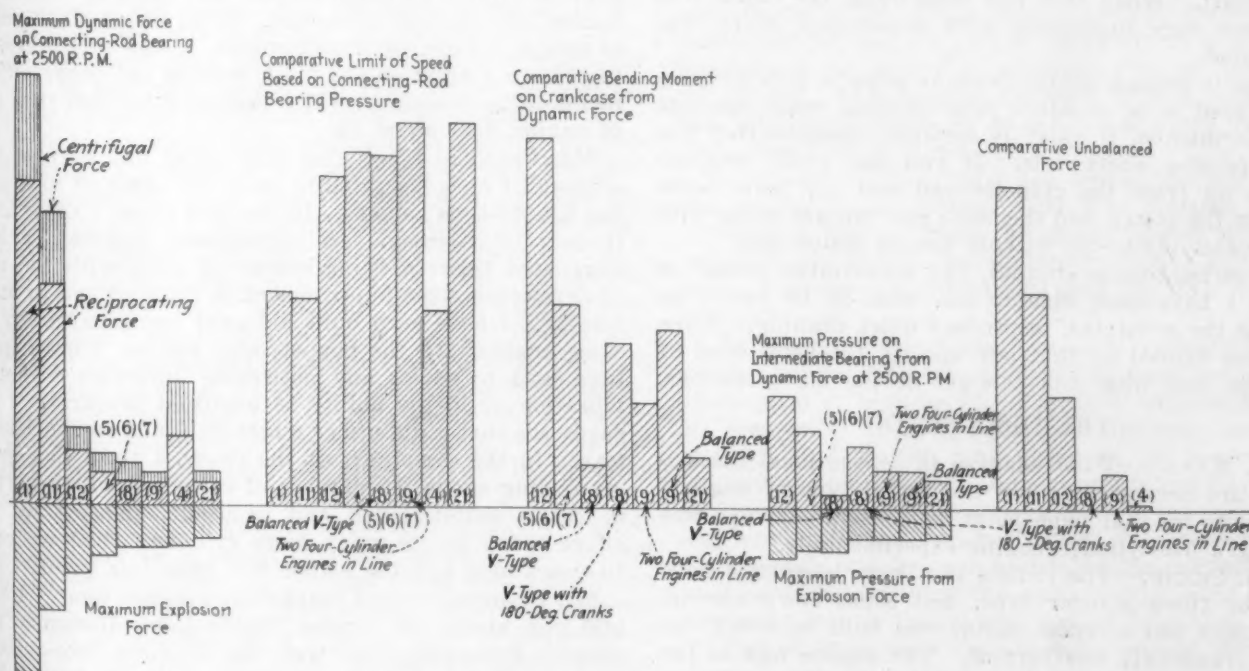


FIG. 22—CHART OF THE COMPARATIVE PRESSURES IN ENGINES OF VARIOUS TYPES

This Drawing Which Is a Combination of Those for the Individual Engines, as Indicated by the Numbers in Parenthesis Following Each Arrangement, Includes the Single-Cylinder (1), Nine-Cylinder Radial (4), Three Six-Cylinder (5, 6 and 7), Eight-Cylinder Balanced V-Type (8), Eight-Cylinder V-Type with 180-Deg. Cranks (9), Eight-Cylinder in Line or Two Four-Cylinder Engines in Line (9), Eight-Cylinder in Line Balanced (9), Two-Cylinder 45-Deg. (11), Four-Cylinder (12), and Eight-Cylinder Opposed (21) Arrangements. All Engines Have 300-Cu. In. Displacement. The Bore Equals the Stroke. The Pistons Are Cast Iron; the Connecting-Rods, Steel. The Connecting-Rod Bearing Is Based on 1 Sq. In. for Each 1000 Lb. of Explosion Pressure. The Explosion Pressure Is 300 Lb. per Sq. In. of Piston Area. The Limit of Speed Is Comparative Only and Is the Speed at Which the Maximum Dynamic Pressure on the Connecting-Rod Bearing Equals 1000 Lb. per Sq. In. The Connecting-Rod Ratio Is 4 to 1

which the speed of the lifter is constant; that is, if the engine is turning at 1000 r.p.m., the linear speed of the lifter over that 10 deg. will be exactly the same from one point to the next. In our practice, the amount of lift happens to be about 0.001 in. per deg. of camshaft rotation. Actually, that does not produce a quiet engine, according to modern standards. I find, in the West, that 2 deg. per 0.001-in. lift is probably a very good figure, and some engines have been built with as much as 3 deg. per 0.001 in. Engines with so slow a lift are very erratic on timing when heated up; but, within reasonable limits, that makes very little difference.

Another advantage of this type of cam is that the adjustment of clearance need not be so accurate. When a tangent cam and an ordinary lifter are used, the adjustment must be at one spot or the cam will be noisy. In this respect, the adjustment can vary 5 or 6 deg. without creating any trouble. That is purely a question of design.

LUBRICATION

The greatest aid in making an engine quiet is plenty of oil in the right place. Nothing has ever been found to take the place of oil. In other words, the greatest thing we can do to produce quietness in running is to have generous bearings, mostly without oil-grooves, which have been greatly overdone in the past, and properly designed to maintain a film of oil over the surface, the oil being the only known way of taking up backlash of an amount that varies with the engine temperature and all the other conditions that occur in operation.

Only within the last year have I believed that oil could make so much difference. One small engine with which we experimented, although it ran perfectly well with no apparent sign of underlubrication, was so noisy with splash-feed oiling that we concluded the only safe thing to do was to put on pressure-feed oiling and flood the crankshaft. When that had been done, the rattle that had been very unpleasant with splash-feed oiling was eliminated.

Large wristpins, nearly twice as large in area as those which used to be standard practice some years ago, are well worthwhile, if quiet is desired. Long-skirted pistons are also worthwhile. If you can avoid scraping all the oil from the cylinder-wall and can leave some between the piston and the wall, you can get along with much looser piston-fits without having piston slap.

In overhead-valve engines, the rocker-arm pivots, so far as I have been able to see, need to be nearly as large as the wristpins, to produce quiet running. When you have figured all that out, specify the right kind of oil; then buy what you can get at the filling-stations.

THE DISCUSSION

R. B. MANN³:—What changes in conventional chassis-design are necessary to use the radial type of engine? It seems to me that someone at Syracuse a year ago was building a five-cylinder engine experimentally.

H. M. CRANE:—The radials that have been used have been the three-cylinder type, and some two's abroad. Some years ago a radial engine was built in which the engine crankshaft was vertical. The engine was in the rear of the car and was of the rotating type. I was speaking simply of being able to put it into a chassis of

the conventional type now. I cannot see how more than three cylinders could be used, and even three could be used only with difficulty.

DONALD BLANCHARD⁴:—Is a short stroke of advantage in reducing torsional vibration?

MR. CRANE:—In certain types of crankshaft a short stroke has a distinct advantage, because it greatly reduces the developed length of the crankshaft, the throws become much shorter, the crank-arms become much shorter and, with crankshafts of the diameter now commonly used, the pin bearings and the main bearings even overlap. For instance, The Pontiac now has a 2-in. crankshaft on a 3¾-in. stroke, providing ¼-in. overlap between the pin and the main bearing. That goes a great way toward stiffening the crankshaft for a given amount of material and therefore makes the torsional periods occur at higher speeds.

CHAIRMAN NEIL MACCOULL⁵:—Does anyone know whether the relative cost of taking care of a 12-cylinder engine is much greater than that of a 6?

MR. CRANE:—We have some 6-cylinder engines with 12 spark-plugs, too.

W. S. PEPPER⁶:—Mr. Crane did not mention the firing order. We have changed the firing order to 1-4-2-3-6-5, primarily because an unbalanced effect existed due to the reciprocating of the sleeves of a Knight engine that is not prevalent in a poppet-valve engine. A poppet-valve engine has only a light valve that moves up and down, whereas both the inner and the outer sleeves of a Knight engine have considerable mass. This tendency, which, in the Knight type of engine, might be called more or less of a fault, is now being overcome by the use of a light steel sleeve rather than the heavy cast-iron sleeve that has been used in the past.

In answering Mr. MacCull's question about maintenance, a Knight engine that is the largest now in general service in motorcoaches has recently been overhauled after a year of service. After about 80,000 miles of service for one particular engine, it was only necessary to remove a shim on the main bearing, no other adjustments being necessary, which goes to show that that type of engine does stand up.

MR. CRANE:—I am glad that point has been raised, although I have hesitated to go so far afield as to discuss the Knight-type balance. In the first place, I know about it only by hearsay. In poppet-valve engines, I have alternated between firing orders on sixes with the hope of developing some improvement in running and in manifolding. I have even built different crankshafts for the same engine. In the poppet-valve engine, I have never been able to detect any noticeable difference either in vibration or in the ability to manifold properly. I can easily see that a difference might be found in the Knight type. In the early part of the paper, I tried to express my feeling about the number of cylinders which is, that in really well-designed and well-built engines we can afford today to use many more cylinders than we could 10 years ago, and the owner will have less grief.

Mr. Pepper mentioned crankshaft-bearing wear. I have told you about the United States Long Distance run-about. Preceding that was the Peerless two-cylinder engine which required a complete take-up every 5000 miles. The four-cylinder Pierce was better but was not particularly good. With well-designed shafts properly lubricated and run at correct speeds, we unquestionably expect an almost indefinite life, especially if we use case-hardened shafts, as has been done by the International Motor Co.

³ M.S.A.E.—National Institute of Inventors, New York City.

⁴ M.S.A.E.—Technical editor, *Motor World Wholesale*, Philadelphia.

⁵ M.S.A.E.—Automotive engineer, research department, Texas Co., New York City.

⁶ Jun. S.A.E.—Manager Eastern coach service, Yellow Cab Co., New York City.

CHAIRMAN MACCOULL:—You spoke about the greater part of the noise of the valve being in its seating. Does not the opening of an exhaust-valve against the pressure in the cylinder cause more impact than the closing of it?

MR. CRANE:—I have never been able to find out whether it is so. What we are after mostly is "sidewalk quietness" and quietness under part load. The full-load noise is pretty well covered up by other noises that we are unable to remove. I believe that the seating of the valve produces the greater part of the noise.

H. S. DURLAND:—If we can take seriously some of the performance charts that we see, the economy of an engine is best at relatively high speeds. If we are to get the same performance, hill-climbing power and economy of operation out of a car, would not that tend toward higher rotative-speeds rather than lower?

CHAIRMAN MACCOULL:—In how many cases do you think the users of cars, except possibly motorcoach owners, care much about the efficiency of the engines? We have talked about efficiency from the theoretical point of view for a long time. To get extraordinarily higher efficiencies, as measured by miles per gallon on the road, or ton-miles per gallon, than are now secured is possible. But the buying public, either unconsciously or deliberately, seems to pay practically no attention to the possibility of getting the best efficiency.

MR. DURLAND:—Why do the motorcoach people not take that into consideration, when economy of operation is essential?

CHAIRMAN MACCOULL:—The answer I have always received to that question is that the cost of the fuel consumed, which is apparently what is meant by economy, is so small a proportion of the total cost of operating a vehicle that it is ignored.

If I am not mistaken, the Fifth Avenue Coach Co. some years ago did all it could to get the greatest number of miles per gallon from the fuel. I believe to use slightly richer mixtures and get quicker acceleration, and therefore more passengers carried per mile, was found to be more economical, than to try to get the greatest possible number of miles per gallon.

F. B. HANFORD:—Regarding firing-order, my associate had some experience in changing the firing order from the conventional 1-5-3-6-2-4 to 1-3-5-6-4-2. In that way he seemed to get a sort of pendulum action in the manifold. He placed a drip-bottle at each intake port and, with the conventional firing-order, the drip-bottles filled very quickly. With the second method of firing, very little liquid was collected in the bottles and he was able to lean the carbureter mixture considerably. How it affects the vibration we do not know because we had no means for measuring it. But the reduction in the deposit from the manifold was very marked, probably due to the regular pendulum action of the gas in sweeping back and forth.

MR. CRANE:—We have tried practically all the possible firing-orders on a six at different times, in an attempt to see whether any one of them made manifold design easier. We never could find enough difference between any two to justify picking a firing-order on the basis of manifold design. In other words, we could always modify the manifold to fit any firing-order.

I should like to say something about gas economy in connection with high engine-speed, because that has been

one of the most manhandled problems ever since persons abroad began to talk about high-speed high-efficiency engines. In the first place, the engines used abroad are not intrinsically efficient. In the second place, we have the testimony of an eminent German authority that they are not even high-speed any more, as compared with ours. In other words, the average European engine turns fewer revolutions per mile in high gear than the average American engine, other than the Ford, the Chevrolet and possibly one other.

What upsets the question of economy so much is the fact that we hardly ever run at full load on the level and that before we can discuss economy we must consider the weight of the vehicle and its hill-climbing ability in high gear, the latter point being of extreme importance.

The greatest saving that could be made in gasoline in this Country would be obtained by lowering the gear-ratio on every automobile 20 per cent. If this were done, we should save almost 20 per cent in gasoline. Without question an average American car will go nearly 20 per cent farther when geared 4 to 1 in the rear axle than when geared 5 to 1. That is simply due to the fact that in the way cars are geared now a large part of the gasoline is used in turning the engine and very little in driving the car. The same result can be obtained, of course, by making the engine smaller and maintaining the same gear-ratio. Some day, when the public wants gasoline economy, that will be much the easiest and simplest way to get it; it can be secured in that way almost over night.

I entirely agree with the statement that the important thing in this Country, from the early days of the railroad down to the present time, is to move the traffic. We have always been told how much more efficient in coal consumption British locomotives are than ours; but when it comes to moving a ton of freight, they are not in the same class; and the same thing is true of passenger-cars. The public wants certain features in a passenger-car that are just as important to it as are soft cushions to sit on and a beautiful color on the outside. At present, with gasoline between \$0.20 and \$0.30 per gal., gasoline economy per se is not considered important; and, relatively, it is not.

A MEMBER:—Mr. Crane has stated that by running the engine faster you will get less economy than by running it slower, when the car is geared 4 to 1. It seems to me if you run the engine faster you will get more economy of revolution, and in that way more economy.

MR. CRANE:—To explain the point verbally is a little hard. In the first place, many engines are not more economical at high speed. Very few engines are nearly as economical at 2500 r.p.m., for instance, as at 1200 r.p.m. That is only one phase of it, however. The important thing is that the slower the engine is run at a given car-speed for a given size of engine, the more efficiently will the fuel be burned, the more work proportionately will be done in driving the car, and the less will be done in driving the engine. The engine requires power to turn it that is nearly proportional to its speed, in fact, a little more than that because of the pumping losses.

To run the engine 20 per cent faster, to drive the car at a certain speed having 20 per cent more explosions that are relatively 20 per cent less powerful, more gasoline will be used than in running at the slower speed. A curve of gasoline consumption will show the reason. The gasoline consumption on a throttle curve works

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* M.S.A.E.—Engineer, Joseph A. Anglada, New York City.

just the other way. If you begin with the gasoline consumed per horsepower-hour when wide open at 1500 r.p.m., then slowly shut the throttle which slows the engine down, the gasoline-consumption per horsepower-hour will go up rapidly. It may be as low as 0.60 lb. per hp-hr. at full throttle; and, at part throttle, around 1.00, 1.25 and even 1.50 lb. per hp-hr. To drive a car at 25 m.p.h. takes about the same horsepower, no matter how fast the engine runs, if the car weight and the other conditions are the same.

A MEMBER:—The reason we do not have the type of engine that Mr. Crane advocates and is able to build is simply the concession that is made to everyone of providing engines that will give rapid acceleration and avoid gear-changing. The American public does not like to change gears. It does not know how to use gears and will not learn. As a consequence, most of the motor-car problems of 1912 and 1913, such as clutch troubles and transmission troubles of various sorts, have totally disappeared in the modern product, due to the fact that the engines of today are run fast. Consequently, we must pay the price of very much higher consumption of fuel and, when cars are run fast, of considerably more vibration.

A MEMBER:—Is bumping produced in the same way as dynamic unbalance?

MR. CRANE:—Not as I describe it. The bumping that I am talking about is purely the result of a type of explosion. It is pretty indefinite to me yet. I had a three-bearing six-cylinder engine that had a distinct

low-toned bump while going from 25 to 30 m.p.h. on a level road, in which case the throttle was probably not more than one-third open. There did not seem to be any reason that it should bump. At one time I was informed that the bumping was due to the three-bearing crankshaft. I now have a three-bearing crankshaft engine that does not bump at all. It is the same in size, but with different cylinder-construction and different manifolding, so, obviously, it cannot be the shaft alone that caused the trouble, although it may have been a contributing cause.

While investigating the cause of this bump, we made a test to obtain the maximum and the minimum explosion-pressures in individual cylinders running under a fixed throttle-condition. We set the engine at 1000 r.p.m. and pulling about two-thirds the maximum torque, so that it was considerably throttled and apparently running smoothly. We first set an Okill indicator so that it just lifted occasionally, in which case we might say we were measuring the maximum pressure ever reached in that cylinder. We then set it so that it followed every explosion, a thing that was easily done. In some cylinders the variation between the two pressures was from 10 to 15 per cent; in others, the variation was nearly 50 per cent. I do not know the reason. I think it is "tied up" with the condition of the mixture, the turbulence, the kind of ignition, and many other things. Something of that sort causes the bumps with this very irregular explosion-pressure. They do not occur only at full load. At full load, of course, they are more marked, but at part load they are still very marked.

INDUSTRIAL ACHIEVEMENT

WITHIN the span of a single life may be written the record of industrial achievements that more profoundly affect human welfare than the combined industrial achievements from the beginning of the Christian era down to the Nineteenth Century. Within the span of two lives may be written down our history, as a nation.

The founders of this Nation and their descendants for almost 50 years looked out upon an industrial world that was but little changed with the passing of the centuries. Transportation by land still comprehended the slow progress of the horse and the ox; upon the ocean the billowing sails of wooden ships afforded the only means of maritime communication.

Washington traveled to and from Mount Vernon by the same means of transportation that Caesar used—the horse upon land, the sail or oar upon the water. John Marshall, the greatest of Chief Justices, wrote his opinions by the light of the tallow dip or the oil lamp, just as Martin Luther in 1517 may have written his famous theses that he nailed

to the church door, or as Plato may have written his dialogues 400 years before the dawn of Christianity.

The great inventions that were to make possible modern industrialism, that were to give opportunity to modern industrial leaders and that were to create a demand for raw materials in undreamed-of quantities were yet undiscovered when the Declaration of Independence was signed on July 4, 1776, or when the Constitution of the United States was promulgated 13 years later.

Little of significance in modern industrial development antedates the beginning of modern chemistry under Lavoisier, who died under the knife of the guillotine at Paris in 1794, after a plea for mercy had been denied by the President of the Committee of Public Safety, with the statement that the Republic does not need scientists. Time has proved the fallacy of that doctrine. If humanity is to progress, if mankind is to seek greater advancement, it can come only through cooperation of government with industry and both with science.—M. L. Requa.



Tools and Fixtures for Service-Station Maintenance Work

By A. H. LEIPERT¹

TRANSPORTATION AND SERVICE MEETING PAPER

Illustrated with PHOTOGRAPHS

ABSTRACT

WHAT constitutes service that is satisfactory to motor-truck and motorcoach owners is enumerated, and the achievement of such service is said to depend upon the direct control and supervision of the vehicle builder over the policy, personnel, methods, location, size, and equipment of the service station. An owner should be able to obtain from stock in the service station any required replacement part for his vehicle, and, in large cities, to get them at any time of the day or night and on holidays. He expects to find an organization of men experienced in the repairing and maintenance of his particular make of vehicle and to receive honest technical advice based on superior knowledge. Speed and accuracy in repair work are often of greater interest than the cost.

Such superior service can be rendered only by organizations having the best facilities, experienced mechanics, expert supervision and tools and fixtures especially adapted to each repair operation. Work in the average repair-shop is classified as (a) tearing down the chassis; (b) overhauling the engine and associated units; (c) overhauling the transmission and rear axle; (d) precision work requiring machines and special tools; (e) cleaning, testing and inspection; and (f) operation of wrecking truck and emergency service.

Control of the stock of replacement parts in more than 100 service stations is maintained by the company with which the author is connected in such a way that branches in different geographical territories can draw upon centrally located division stocks for replenishment. All parts are supplied by the general service department in Plainfield, N. J., adjacent to one of the company's factories. Special-equipment service parts and maintenance tools and fixtures are supplied by the Long Island City plant.

Each of the enumerated classes of repair work requires tools and fixtures adapted for it, but the author confines his paper to special tools and fixtures that are used to advantage on the company's own make of trucks and motorcoaches. Many special devices are not precision tools but rather tools of convenience, such as wrenches, pullers, holding fixtures, and stands. In general, a fixture serves better and more reliably when its purpose is specific and it is not called upon to perform work on many different makes or models. Sturdy well-designed stands are more necessary for repairs on heavy truck-parts than for passenger-car work.

Special devices described are a dolly with three jack-screws that can be run up to support the jackshaft housings and bevel-pinion housing while the cap-screws and nuts are being removed and the transmission lowered to the dolly; a transmission stand to which the transmission is wheeled in the dolly so that work can be done independently on the transmission and countershaft; a smaller stand for holding the complete transmission assembly; an engine-stand on which the engine can be revolved to any angle by a hand-operated worm and gear; a main-bearing boring-fixture that assures alignment of all the crankshaft bear-

ings and produces a mirror-like surface finish; a connecting-rod straightening and aligning fixture; a connecting-rod-bearing boring-fixture, and an engine valve-cap removing-spanner having a 6-ft. bar to which two men can apply their strength for removal of the most obstinate valve-cap.

Tools such as those described are designed for the performance of accurate work in the least possible time, and they help to make possible a flat-rate service system. Others of similar nature are constantly being designed and made. Any idea or need suggested by the company's service stations is studied, and the required tool or fixture is developed, made and tested at the Long Island City plant. When approved and built in quantity, the tools are available to all the company's branches and to fleet owners who have their own shops. Ways of overcoming service difficulties are reported by the various branches and, whether they be service methods or special devices, are broadcast to all branches. Thus each individual service station has the advantage of the cumulative experience and ingenuity of the entire organization.

SERVICE is satisfactory to the motor-truck and motorcoach owner when it is (a) obtainable at points located conveniently to his operations, (b) rendered quickly with minimum loss of normal operating time and (c) rendered at a minimum cost that is consistent with (d) accurate and dependable workmanship.

Service is satisfactory to the truck builder when the customers are satisfied. The volume of repeat-order business and attendant new sales will measure the degree of satisfaction the service is giving.

The achievement of these elements of satisfactory service depends largely upon the control exercised by the builder over the shops offering service on his product. Direct control and supervision are important, almost essential in fact, and should embrace control over (a) service policy, (b) service personnel, (c) service methods, and (d) location, size and equipment of service stations.

Only if all service stations are branches operating under the parent company can strict and uniform adherence to the ideals of accuracy, efficiency and fairness embodied in a sound service-policy be assured. Centralized control also acts as a clearing-house for information on service difficulties and for helpful service data and experimental information. Back of each branch is the cumulative experience of all the other branches.

SERVICE THAT USERS EXPECT

Truck and motorcoach users must have dependable service if they are to realize the fullest returns on their investments. They expect such service and their purchases are influenced more and more by service considerations. The owner wants service stations located so that he can secure replacement parts and repairs without making a long out-of-the-way trip. There he should be able to secure from stock any required replacement part for his vehicle. The duty of each service station is to supply obsolescent non-interchangeable parts so long

¹Service department, International Motor Co., Long Island City, N. Y.

as any trucks depending on such parts are in use in its territory.

In the larger cities, parts and service should be obtainable at any time of day or night and on New Year's Eve and Thanksgiving Day. An owner-driver who is working on a contract will thus be enabled to obtain needed parts and repairs without undue loss of working time or delay on his contract. Where such 24-hr. service is obtainable, users are more likely to obtain parts after conventional working hours than during them.

A sound system of stock control is essential so that the delay in replenishing the supply of parts at the station may be the minimum and so that the total inventory can be kept down. The builder of Mack trucks controls the parts stock within geographical territories in such a way that the branches draw for replenishment on stocks at centrally located divisions. All parts are supplied to the divisions by the general service department located at Plainfield, N. J., adjacent to one of the Mack factories, where sufficient stock is kept to fill requisitions as they are received. The general service department stock is maintained by an allotment taken from current production of the factories. Special-equipment service parts and maintenance tools and fixtures are supplied to the general service department by the company's Long Island City plant.

In addition to an adequate supply of replacement parts, the user expects to find at the service station an organization of men who are experienced in the repairing and maintenance of the make of truck he is using. The manufacturer should feel morally bound to render customers every reasonable assistance in keeping their trucks out of the repair-shop and in working condition. Failure to do so often means serious loss to the customer and he may blame his misfortune on the truck, whether justly or not. Loss of his good-will is expensive, for a satisfied user who has profited by his truck is not only

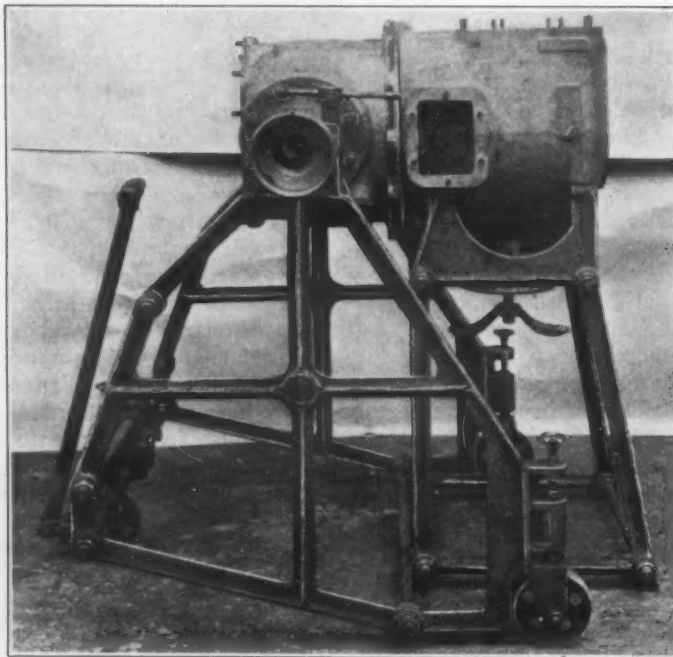


FIG. 1—COMBINATION DOLLY AND TRANSMISSION-STAND
After the Dolly at the Left Is Wheeled under a Truck and Adjusted to the Jackshaft and Transmission Assembly, the Assembly Is Disconnected and Wheeled to the Transmission-Stand at the Right. The Holding Screws Are Then Removed and the Two Stands Are Separated So That Work Can Be Done Conveniently on the Transmission and on the Jackshaft Assembly. The Adjustable Jack-Screws of the Dolly Make It Possible To Register the Screw Holes for Replacement of the Holding Screws on an Uneven Floor or in a Truck Chassis That Is Lower on One Side Than on the Other

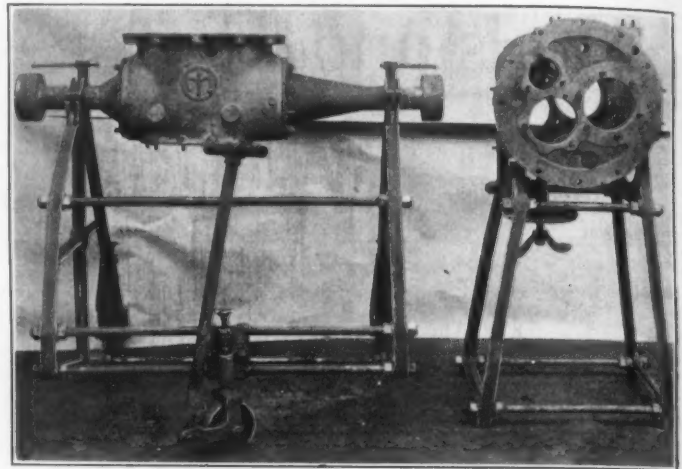


FIG. 2—DOLLY AND TRANSMISSION-STAND SEPARATED
Work Can Proceed Simultaneously on the Transmission and the Jackshaft and Differential Assembly. The Latter Assembly Can Be Rotated into Convenient Working Position and Held There by a Clamp at Either End around the Jackshaft Housing. When Work on the Two Units Is Finished, the Two Stands Are Brought Together and the Connecting-Bolts Replaced

a prospect for a repeat order but is also an efficacious advertising agency. When a user tells his troubles to the service manager or inspector, he wants to feel confident that he will receive technical counsel that is based on superior knowledge and is honestly given in his own best interests.

QUICK ACCURATE WORK REQUIRES SUPERIOR FACILITIES

Contact with owners shows that speed and accuracy in the performance of repair work are often of greater interest to them than is the cost of repairs. Some organizations place too great emphasis on the charges for service and upon miscalled "free" service. While the extreme policy of giving no guarantee service is shortsighted, the other extreme of free repairs and parts replacements is not fair to the customer who cares for his truck and is reasonable in his demands. Nothing worthwhile is given away; someone pays for free service and the cost usually is collected in advance with the purchase price of the vehicle. No business man objects to paying a reasonable charge for proper service, but he will combat almost any charge for work that has proved slovenly or that has caused him loss through unreasonably protracted idleness of his truck.

The object of service should be to keep each vehicle continuously at work by forestalling mechanical difficulties so far as possible by timely advice, inspection and adjustment and, when shop work is necessary because of natural wear or accident, to make accurate and lasting repairs at a time that is most convenient to the owner, in the minimum of time and for a just charge. Obviously, such superior service can be rendered only by organizations that have the best facilities. Accurate and dependable repairs quickly accomplished are the product of experienced mechanics working under expert supervision and employing tools and fixtures that are especially adapted to each repair operation. When I say experienced mechanics, I have in mind the trained specialist rather than the Jack-of-all trades. Good mechanics become better if they are required to work on only one make of truck and particularly on the class of work at which they are most efficient.

The usual repair-shop classifies work as follows:

- (1) Tearing down the chassis. This consists of removal of the engine, transmission, steering-gear, radi-

- ator, axles, and the like; and work on springs, brakes and control mechanism
- (2) Overhaul of engine and associated units
 - (3) Overhaul of transmission and rear axle
 - (4) Precision work that requires the use of machines and special tools
 - (5) Cleaning, testing and inspection
 - (6) Wrecking-truck operation and emergency service

SPECIAL TOOLS AND FIXTURES EXPEDITE WORK

Tools and fixtures of one special nature or another are required to accomplish each of these classes of work, but I shall concern myself in this paper only with the special tools and fixtures that we have found can be used to advantage in our own shops. Many special tools and fixtures are not precision tools but rather tools of convenience. Special wrenches, speed wrenches, pullers, holding fixtures, and stands are of this class.

In general, a fixture can be made to serve better and

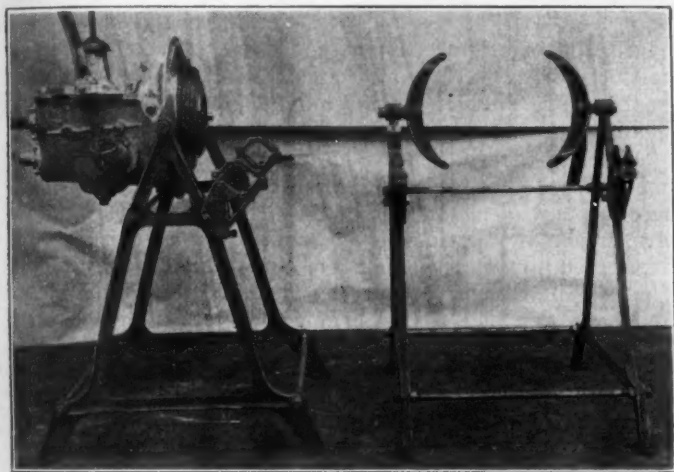


FIG. 3—LIGHT STAND FOR COMPLETE TRANSMISSION

This Was Designed To Hold the Complete Transmission Assembly of the Mack AB Truck When It Is Not Desired To Separate the Two Units. The Clamp Brackets Extending from the Side of the Stand, As Shown Clearly in the View at the Left, Are Used to Hold the Bevel-Gear-Housing Assembly. The Side View at the Right Shows the Curved Brackets That Hold the Transmission Unit

more reliably when its purpose is specific and it is not called upon to perform work on many different makes or models. Too many adjustments on the tool lead to structural weakness and inaccuracy in the work it performs. Sturdy and properly designed stands are more necessary for truck repairs than for passenger-car repairs, for the weight of many truck units is more than the average mechanic can lift conveniently. For example, the transmission and bevel-gear assembly of a Mack 5 or 7½-ton chain-drive truck weighs about 750 lb. when filled with lubricant. It is held to the frame at three points by right and left jackshaft-frame bracket-caps and by two large transmission front-support bolts.

To remove four cap-screws and two nuts, is not difficult, but since the design logically provides for removal and installation of the transmission from beneath the chassis, leaving the body in place, a fixture, in this case a dolly, is provided to do the work of six men and with greater safety and speed. This dolly is wheeled under the truck and each of the three jack-screws is spun-up by the hand wheels to support the two jackshaft housings and the bevel-pinion housing at the front. After the cap-screw and nuts are removed, the transmission is lowered and pulled over to the transmission-stand shown in Fig. 1. The three jack-screws are not interconnected and by their independent adjustment the transmission can be raised into position quickly for easy replacement

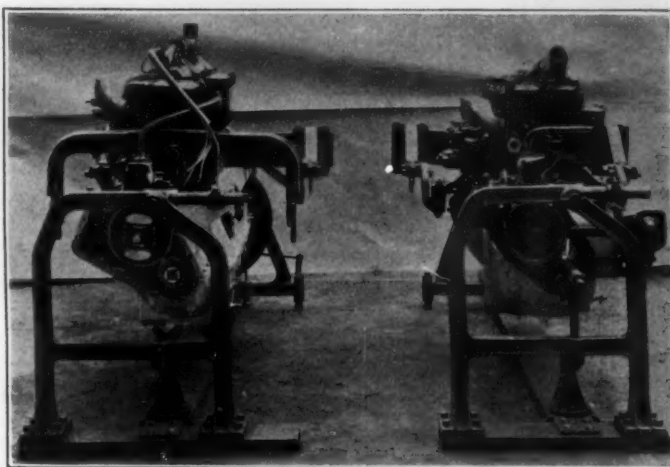


FIG. 4—STANDS FOR TWO ENGINE MODELS

A Model AC Truck Engine Is Seen in the Stand at the Left, with Crankcase Gear-Cover Removed. In the Stand at the Right Is Mounted a Model AB Motorcoach Engine. The Engine Can Be Rotated in the Stand to Any Desired Angle for Convenient Work by a Worm and Gear on the Other End of the Stand

of the holding screws, the jack-screws compensating for unevenness of the floor or for a frame that is lower on one side than on the other because of worn tires or unequal distribution of load.

TWO-PART TRANSMISSION-OVERHAUL STAND

The transmission is placed in this stand for disassembling and overhauling. The transmission unit and bevel-gear-housing assembly usually are united when they are placed on the stand. The transmission proper is held to the right portion of the stand by a screw that enters the drain-plug hole. The bevel-gear housing is secured in the left portion by clamps that hold each jackshaft housing. The screws that hold one transmission unit to the other are then removed and the two parts of the stand are separated as illustrated in Fig. 2. The bevel-gear housing is rotated in its stand to the most convenient working position. Work can proceed on both units at the same time and after work on both units is completed the two parts of the stand are brought together and the connecting-bolts are replaced.

The complete transmission assembly can be carried by one fixture, as shown in Fig. 3, when it is not desired to separate the two units. This smaller stand is used

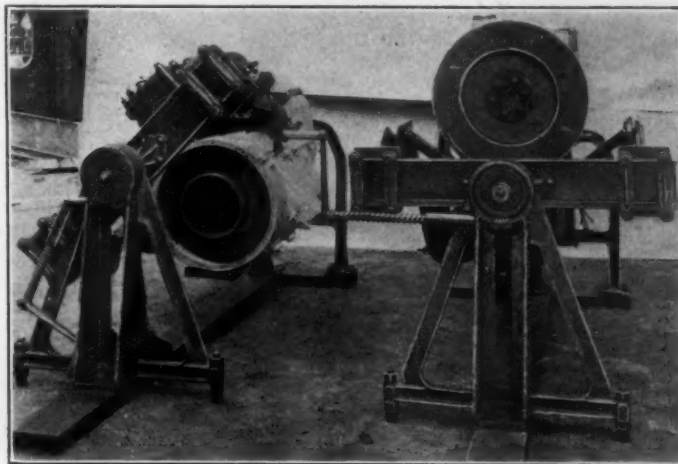


FIG. 5—STANDS WITH ENGINES INVERTED

On the Stand at the Right the Worm, Worm-Gear and Crank Handle for Rotating the Engine Are Shown with the Gear Cover Removed. The Stand at the Left Shows the Handle Turned Down out of the Way of the Mechanic. The Worm and Gear Are Self-Locking

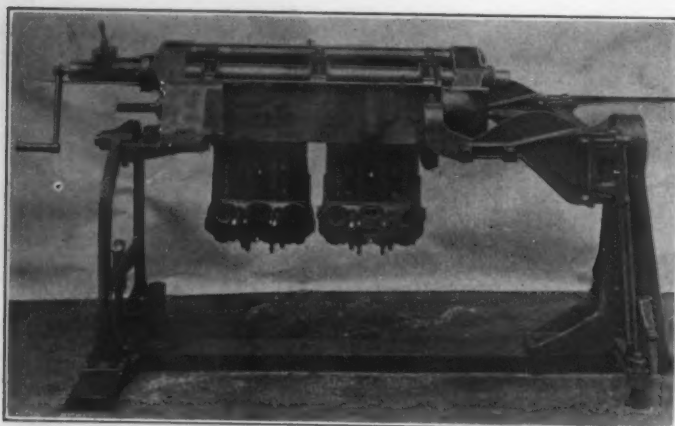


FIG. 6—SIDE VIEW OF ENGINE-STAND AND MAIN-BEARING BORING-FIXTURE

Absence of Side Rails Permits the Mechanic To Stand Close Enough to His Work for Comfort While Working on the Bearings. The Engine Has Been Inverted, the Lower Crankcase, Crankshaft, Pistons, and Connecting-Rods Removed, and a Boring-Fixture Mounted Preparatory To Boring the Main Bearings

to hold the transmission of our model AB truck. It is light yet rigid. The clamp brackets that extend from the side of the fixture, as seen in the left view, are used to hold the chain-drive model AB bevel-gear-housing assembly.

ROTATABLE ENGINE-OVERHAUL STAND

The engine-stand shown in Fig. 4 is also light in comparison with its great strength. The left view shows a model AC engine with the crankcase gear-cover removed to expose the timing-gears and governor. In the stand at the right is mounted a model AB motorcoach-engine with the crankcase gear-cover in place. The engine can be turned in these stands to any angle desired for convenience by a self-locking worm and gear driven by a handle from the other end of the stand. One of the chief features of this stand is that the absence of side rails permits the mechanic to stand close enough for comfort while working on the bearings. Fig. 5 shows the stand-operating mechanism with its cover removed, at the right, to disclose the worm and gear. The operating handle is in working position. In the view at the left the handle is shown folded down out of the way. The engines in the stands are partially and completely inverted preparatory to removing the lower crankcase and other parts. In Fig. 6 these parts have been removed and a main-bearing boring-fixture is shown installed ready to bore the main bearings.

WHY A MAIN-BEARING BORING-FIXTURE IS USED

I will explain why we use a boring-fixture. New main-bearings are fitted to the crankshaft in several ways, as by (a) hand scraping, (b) reaming or line-reaming, (c) burning-in, and (d) boring.

Hand scraping is the earliest method used and requires only simple hand-tools plus plenty of time and a man who knows how. After the bearing shells are seated in the crankcase, blue is applied to the journals of the crankshaft and an attempt is made to line-up the upper bearing-halves while trying to keep the front bearing at a height that will not move the timing-gears off their pitch-lines, which would cause excessive noise and wear. This requires many hours of exacting work. Then the lower halves are fitted to the caps and also scraped-in. While the finished bearing may appear to have a fair bearing-surface, it really consists of a number of scooped-cut depressions and alternate peaks of metal on

which the journals ride until the high spots are flattened out by use.

Bearings that are well fitted by the hand-scraping method are always tight at first and must be run-in very carefully. Often it is necessary to run the engine on a belt for a number of hours and follow this by a run-in under its own power, with light load and excessive lubrication. In fact, excessive lubrication and operation at moderate speed for a given period after delivery to customer are advocated to avoid the danger of burned-out bearings.

Since the amount of metal to be removed from a replaced bearing is considerable, expanding hand-reamers have been used, but the bearings must still be finished by hand scraping after the reaming. This practice naturally led to the use of line reamers designed to keep the bearings in line during the operation. This was a step ahead, and if the line reamer is designed especially for a specific engine model it gives fairly good results. However, as it is a self-centering device and is not very rigid, the results are not as good as are those obtainable with a boring-fixture, and considerable hand-scraping is required to correct misalignment after using the line reamer.

Burning-in bearings seems a rather brutal and crude method, yet the results obtained in a certain light popular car are uniform and not bad. In this case the engines are driven by outside power while the bearing caps are tightened gradually. The frictional heat generated in the bearing causes the bearing metal to flow and conform in shape and size to the crankshaft journal. A stream of lubricant is directed on the bearing during the process.

BORING-FIXTURE AND ITS OPERATION

The main-bearing boring-fixture used in our shops consists of a rigid bar that extends through all the bearings and a bracket assembly to hold the bar in exact position. Adjustable fly-cutters are mounted in the bar, which is fed slowly through the bearings. In using this fixture, the cylinder-blocks should be in place on the crankcase and all stud-nuts tight. The engine support-

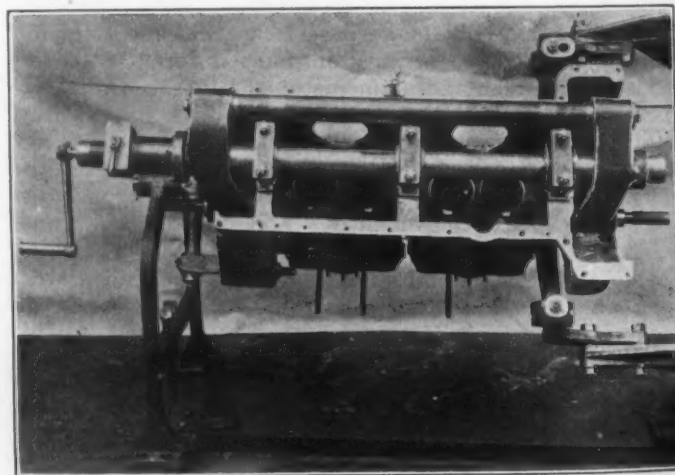


FIG. 7—MAIN-BEARING BORING-FIXTURE SET FOR WORK

The Fixture Consists of Two End-Brackets Connected Rigidly by a Tube, and a Central Boring-Bar Turned by the Handle at the Left. The Brackets Do Not Slide on the Tube and All Center Distances Are Fixed and Cannot Vary. Two Tapered Locating-Plugs on the Brackets Enter the Front and Rear Camshaft-Bearings and Hold the Bracket Assembly Parallel with the Upper Face of the Crankcase. The Distance from the Center of the Locating-Plugs to the Center of the Boring-Bar Is Exactly Equal to the Center-to-Center Distance between the Timing-Gears When Meshed on Their Pitch-Lines. Cutters Are Inserted in the Boring-Bar and Each Is Set by Micrometer Measurements from Each Crankshaft Journal To Bore Its Bearing to a Diameter 0.001 In. Larger than Its Crankshaft Journal. The Edges of the Bearings Are Faced and Filleted with Another Tool Inserted in the Same Fixture

bolt nuts and main-bearing caps and nuts should be tight and their positions marked; in brief, all bolts and studs should be under the same tension as when the engine is assembled ready to run.

Alignment of the bearings is indispensable if the job is to give full satisfaction. How this boring-fixture assures alignment and, at the same time, finishes bearings with a full mirror-like surface with no gouged-out depressions as in a hand-scraped bearing, will be explained.

The engine-stand has been turned in Fig. 7 to show the boring-bar from above. The two brackets are connected rigidly by a tube. No adjustment is provided; the brackets do not slide on the tube. All centers are fixed definitely and cannot vary. This bracket assembly is mounted on the crankcase at three points. Two tapered locating-plugs that enter the front and rear camshaft-bearings hold the bracket assembly parallel to the upper face of the crankcase and the center line through the main-bearing seats. As the distance between the center of the tapered locating-plugs and the center of the holes in the end-brackets for the boring-bar is exactly equal to the center-to-center distance between the timing-gears when meshed on pitch-lines, all possibility of variation that would cause excessive noise and wear is eliminated. This is particularly important when case-hardened and ground helical timing-gears are used. Soft gears may wear in and allow, in a measure, for liberties taken with their pitch-lines by inexact bearing-finishing methods. That is one fault to be found with line reamers, which always center themselves and provide no means for holding to this center-to-center distance between shafts. An element of weakness and opportunity for error exists in boring-bars that are made adjustable. It is well to understand that an aluminum crankcase is not absolutely rigid and many things, such as the gradual relieving of casting strains even after proper annealing or actual compression or stretching of the metal because of the tightening of cylinder, bearing-cap and other nuts, may cause deformation amounting to a few thousandths of an inch. If alignment and accuracy to 0.001 in. or better is expected, the conditions of the assembled engine must be duplicated while boring the bearings and no stress introduced in the bearing-finishing process to disturb this condition or the alignment of any of the parts.

With this boring-bar this condition is assured by providing that the excess bearing-metal be removed by a sharp fly-cutter for each bearing. In the case of a three-bearing crankshaft the cutters are disposed at 120 deg. around the boring-bar. The bar is $2\frac{5}{8}$ in. in diameter and is obviously of a degree of stiffness that will not be affected by the tools cutting soft bearing-metal.

CUTTERS SET BY MICROMETER MEASUREMENTS

The boring-bar, with cutters removed, is pushed through the two brackets and the main bearings are assembled as shown. The cutters are inserted in the bar and each is set from measurements taken from each crankshaft journal. The crankshaft has been verified and straightened and, if necessary, ground before the measurements are taken. Then each cutter is set to bore its bearing to a diameter 0.001 in. greater than the diameter of its crankshaft journal. The translation of crankshaft measurements into cutter-setting measurements is accomplished by a table that includes allowance for clearance. Obviously, the mechanic who makes these measurements must have a good micrometer-touch to

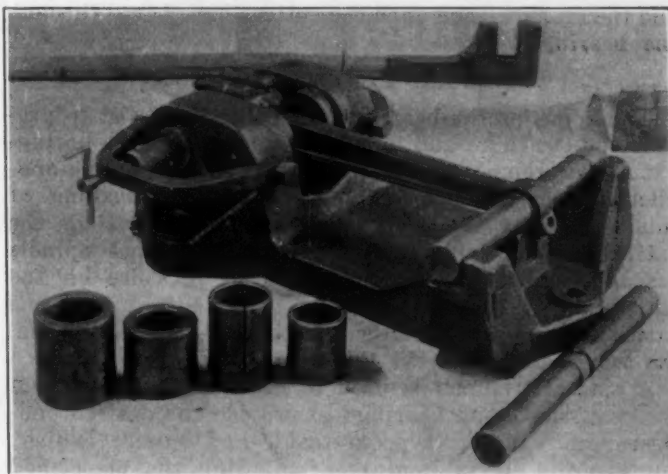


FIG. 8—CONNECTING-ROD STRAIGHTENING AND ALIGNING FIXTURE. This Is Made Particularly Sturdy So That the Rod Can Be Straightened while in the Fixture. The Rod Is Assembled in the Fixture on a Mandrel and Tapered Bushing in the Big-End and Adjusted by the Clamp Set-Screws So That the Sides of the Connecting-Rod Clear the Fixture. Another Mandrel Is Inserted through the Wristpin Bearing and Laid in the Lands of the Fixture. Bends and Twists in the Rod Are Indicated by Relative Clearances between the Ends of the Mandrel and the Vertical and Horizontal Lands and Are So Exaggerated by the Length of the Mandrel That Rectification Is Made Easy.

obtain the desired accuracy of clearance. An error of 0.0005 in. in setting the cutter would make the clearance nil or 0.0020 in. One man is assigned to this work and care is taken that the micrometer parts and tools are at uniform temperature. A man of suitable temperament, even though he be no machinist, can be trained to become an expert in the use of this tool.

The centering of the boring-bar in the bearings is accomplished by adjustment of the clamp-screw and jaw assembly, which is integral with the bracket tube. This clamps to the crankcase flange, and two screws raise or lower the boring-bar as required.

All is now ready to start boring, and the bar is pushed in until the cutters are about to enter the bearings, the turning crank is clamped on, the feed-block nut engaged

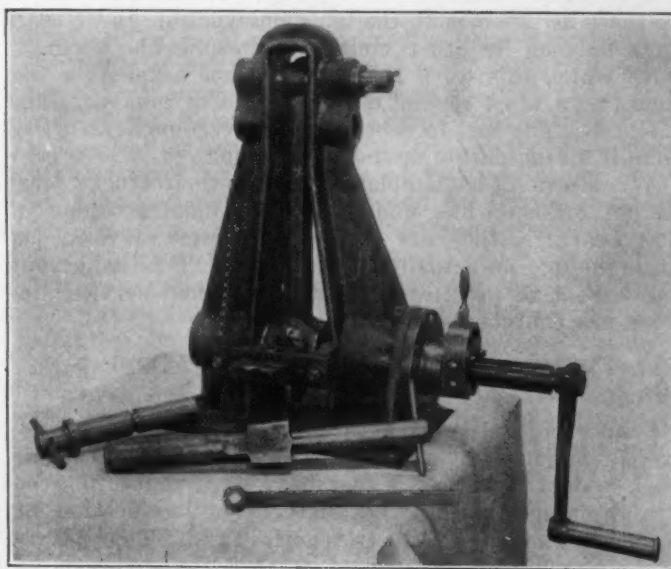


FIG. 9—BORING FIXTURE FOR CONNECTING-ROD BEARINGS. When a New Bearing Is Seated in a Connecting-Rod, the Rod Is Mounted in the Fixture by Hanging It from a Wristpin Mandrel. A Tapered Locating-Plug Is Then Pushed into the Fixture in Place of the Boring-Bar To Center the Big-End Bearing, and Clamps on Either Side of the Rod Are Drawn-Up Tight. The Boring-Bar Is Then Inserted and the Cutter Carried by the Bar Is Set To Bore the Bearing 0.001 In. Larger than the Measured Diameter of the Crankpin in Which It Is To Run.

and the crank turned until the cutters have bored through the bearings.

FACING AND FILLETING THE EDGES

The edges of the bearings must next be faced to provide end-clearance and to cut the fillet, hence the boring-fixture is removed and the main-bearing facing-and-filleting tool is employed. The adjustable bushing of this tool is expanded in the center main-bearing, the ratchet-wrench put on and the feed-nut and spindle assembly used to exert the required pressure on the cutter-bar, which carries three facing-cutters and one cutter for the fillet. After one bearing-face is finished, the tool is turned to cut the other side.

A special trammel is used to make measurements on the crankshaft and bearings to provide the desired end-clearances. It is a type of inside and outside caliper, but has the special feature of allowing the prescribed end-clearances automatically. This trammel bar has several pairs of conical depressions in which the two adjusting set-screws of the adjustable member engage. The distances between these screws and the holes differ slightly so that close adjustment can be made by screwing them in or out. Both screws are kept engaged so that the adjustable member is clamped firmly.

To complete the facing of the center main-bearing the distance between the fillets on the crankshaft is gaged with inside-caliper gage-points and the bearing is cut to conform to the distance between the outside-caliper gage-points, using the lower step on the adjustable-member gage-point. This allows the required end-clearance of 0.003 in.

The inside faces of the front and rear main-bearings are cut next. The distance between the fillets on the crankshaft is measured by the outside caliper points, using the upper step, and this bearing is faced to conform with the distance between the caliper points. This provides a clearance of 0.005 in. when the crankshaft is centered in the center main-bearing.

When the crankshaft is assembled in these bearings and the bearing-cap nuts are tightened to their marked positions, the shaft will turn freely. This is a revelation to those accustomed to the laborious running-in of bearings finished by other methods. Despite the accuracy with which this work is done, the time taken is a few hours as against several days required by hand-scraping methods. The cost in this case for precision work is less than if an inaccurate method were employed.

When owners contemplate the time their trucks must be out of use while undergoing the hand scraping of new bearings, they are inclined to defer the evil day until the engine actually breaks down. This dangerous and expensive practice is eliminated when service stations are equipped with boring-fixtures.

FIXTURE FOR STRAIGHTENING AND ALIGNING CONNECTING-RODS

Connecting-rod bearings are bored with the same degree of precision by another boring-fixture. Before this work is done, each rod is installed in the connecting-rod straightening and aligning fixture for verification or needed alignment, as illustrated in Fig. 8. This fixture is made particularly sturdy so that the rod can be straightened while it is mounted in the fixture, which saves much time. The rod is assembled with a solid crankpin bushing, the inside bore of which is tapered the same as the crankpin mandrel on which the large end of the connecting-rod is mounted and held in the fixture. After the mandrel is seated firmly in the tapered

bushing, the right and left clamp set-screws are adjusted so that the sides of the connecting-rod clear the fixture. The connecting-rod wristpin is replaced by a wristpin mandrel. A bend in the rod is indicated by the relative clearance between the two ends of the wristpin mandrel and the vertical lands on the foot of the fixture. A twist in the rod is indicated by the relative clearance between the ends of the mandrel and the horizontal lands on the fixture. Because of the length of the wristpin mandrel, deviation is so exaggerated that rectification is made easy.

CONNECTING-ROD-BEARING BORING-FIXTURE

When the new bearing is seated in the connecting-rod, the rod is mounted in the boring-fixture as shown in Fig. 9. It is hung from a wristpin mandrel at the top of the fixture while the boring-bar is removed. The tapered locating-plug is pushed into the fixture in place of the boring-bar to center the big-end bearing. While the plug is in place, the clamps on either side of the rod are drawn up tightly, the plug is removed and the boring-bar pushed in. The cutter carried by the bar has been adjusted to bore the bearing 0.001 in. larger than the measured diameter of the crankpin on which it is to run. As in the case of main bearings, a table is used to convert crankpin measurement into cutter-setting measurement with proper clearance allowance. The bearing end-faces and fillets are cut by a facing-tool, which cuts both edges at once.

TIME-SAVING VALVE-CAP REMOVER

A valuable time-saving tool is a valve-cap remover that is not large but holds on like a bulldog. Unfortunately, some men like to replace engine valve-caps in shellac or other ingredients whose qualities are admirable when applied to certain joints and gaskets but are decidedly the reverse for valve-caps. Also unfortunately a drift or chisel instead of the spanner provided for that purpose often is found in the hands of a man who is removing a cap. The result is that stuck valve-caps with damaged lugs are brought to the service station for quick removal. As drilling out a cap is not a quick job, this little fixture is called into service. It succeeds because of its design and great strength. The spanner head is kept constantly in contact with the valve cap with any desired amount of pressure. The lead of the spanner-head screw corresponds to that of the valve-cap threads so that contact is maintained until the valve-cap is screwed all the way out. Two men at the end of a 6-ft. bar will move any cap.

Tools such as those described are designed to do accurate work in the least possible time and to eliminate the element of variation of time and uncertainty, consequently they help to make possible a flat-rate system of service charges that is at once advantageous to the user and safe for the service station. We have many other maintenance tools and fixtures of similar nature and are constantly designing and making more. Any idea or need suggested by one of more than 100 Mack service stations is studied and a suitable device is developed, made and tested at our Long Island City plant. When approved and manufactured in quantity, our tools are available to all branches and to fleet owners who have their own shops.

Methods of overcoming service difficulties as reported from different points are also studied there and the means, whether it be a service method or a special tool, is broadcast to all branches. Thus the cumulative experience and ingenuity of the entire organization are behind the efforts of each branch service station.

The Railroad Freight-Terminal

By BRUCE V. CRANDALL¹

TRANSPORTATION AND SERVICE MEETING PAPER

ABSTRACT

AFTER defining a railroad freight-terminal as a point where road haul ends and saying that perhaps it is better defined as a point where the steam railroad should end, the author names the two kinds of terminal, final and intermediate, and describes their characteristics. He discusses the considerations involved in locating terminals properly and enlarges upon the urgent need for proper coordination of transportation facilities, including motor transport.

A description of the trap-car system used by the railroads is given, inclusive of comment; and the subject of effective handling of heavy materials, such as coal, is treated. Freight congestion in cities and the influence of the manufacturers of railroad supplies on railroad practice are discussed also.

Saying that the location of freight terminals of the future will be dependent upon motor-truck operations and on how well the automotive industry adapts its equipment to this operation and to the elimination of the economic waste of down-town terminals and trap-car movements, the author outlines work that the Society should do toward solving the great problem of transportation and, in conclusion, appends a list of some of the items that must be taken into account in considering present and prospective freight-terminals.

AS the editor and publisher of the *Railway Review*, a technical railway-journal, I took up editorially last year the problem of the railroad freight-terminal and, for a number of months, I have been emphasizing this question because of its transcending importance. While my publishing experience has been a limited one, I have spent my life in practical railroad affairs, first in the railroad-equipment manufacturing-business and then as an officer of a railroad corporation. In my opinion the largest losses in railroading, in time and in money, are to be found in our freight terminals. It is a matter of concern not only to the railroad man but also to transportation men everywhere.

If I am to talk about railroad freight-terminals I want to define pretty clearly just what I am going to discuss. The dictionary definition of the word "terminal" is "Of, pertaining to, or forming a terminus or terminal of something." For your purposes and mine I think I can define a railroad terminal as a point where road haul ends. Perhaps it would be better to say, a point where the steam railroad should end.

Railroad terminals are of two kinds, final and intermediate. The final terminal is at the end of the line. The intermediate terminal is at the point or points where the road haul is interrupted to switch trains and classify them for further road movement, to inspect the rolling equipment and do other incidental things in connection with train operation, including reconsignment.

All intermediate terminals have other functions that are not included in the foregoing statement. They are situated at towns or cities having more or less industrial development and are for the local collection and delivery of freight to manufacturing plants, freight houses and team tracks. Incidental to all these operations, and this applies to final terminals as well, is the necessity for

facilities to handle motive power and rolling-stock. Every terminal, therefore, is complicated in purpose and in the carrying out of the several functions for which it is designed. Every terminal represents a large original investment and a large outlay for operation and maintenance. The organization necessary to operate any terminal is complicated and, as the size or importance of the terminal increases, the intricacies of the organization increase more rapidly as do the details that must be looked after. Supervision seldom keeps pace with these forms of growth, with the result that inefficiency of operation is a normal condition. Inefficiency always means added cost that is pure waste.

RAILROAD FREIGHT-TERMINAL LOCATION

I cannot afford to give any more time or space to defining a railroad freight-terminal, but I trust that the foregoing is enough so that my subject can be clearly understood. To cover so large a subject in any one paper naturally is impossible, therefore some limits must be placed upon the subject, and so I will confine what I have to say more to the locating of the railroad freight-terminal than to anything else. That I may not roam too far afield and also that I may be more emphatic because of illustration, I shall confine myself to the railroad freight-terminal situation as it is found in Chicago. Out of my office window as I dictate I look out over the freight yards of the Illinois Central Railroad, bounded by Lake Michigan, the Chicago River and Michigan Avenue. And because I am going to treat more of the placing of the railroad freight-terminal than anything else, to inquire why railroad freight-terminals are located where they are is only natural.

Not only the railroad freight-terminal that I see daily from my office window but practically every other freight terminal in the Country was located many years ago, having in mind its connections by water and the character of the local conveyance for hauling from the terminal the commodities brought to it in the freight-cars of the steam railroad. Steam railroading had its beginnings at a time when water and the horse-drawn vehicle were the only forms of transportation. Today we have not only waterways and highways, as we had 100 years ago, but we have greatly improved highways. But we are at the threshold of an intensive use of these highways because of the coming motor-driven vehicle. The internal-combustion engine, whatever its future possibilities, has certainly changed our map and, whatever may be your opinion or mine, or the opinion of railroad managements or that of the motor-transport industry, the railroad freight-terminal must be changed to accommodate itself to changed conditions. We have today the waterways, the highways, the railways, and the airways. I think that no man would have the temerity to say that the railroad freight-terminal of yesterday is to remain the freight terminal of today. It cannot so remain. Fifty years ago Chicago was an overgrown village. Its freight terminals were placed at that time for the immediate convenience of the Chicago of that day and there they have stood, to be added to, shifted, enlarged, and improved, but all from a 50-years-ago standpoint. They must be placed, not only from the standpoint of

¹ Editor, *Railway Review*, Chicago.

1926, but if we place them wisely we will take into consideration, so far as we can with our human limitations, what will be the needs of 1976. So much for a brief reference historically to the railroad freight-terminal.

Why should I, limited by my experience to the field of steam-railroad transportation, attempt to bring anything before you gentlemen today, whose experience has been in a very different field, that of the automotive industry? For just this reason: Until we coordinate all forms of transportation, thereby lessening economic waste and increasing efficiency, the public pays the bill and the brakes are dragging on the wheels of civilization.

COORDINATION OF TRANSPORTATION

Before I get to the point where I want to give you my ideas on just one section of the problem of the railroad freight-terminal, I want to say that the compelling reason for my standing before you today is to say to you, with all the emphasis that I can give it, that nothing is of any greater importance in our scheme of things than in the coordinating of all forms of transportation. Production and consumption wait ever on distribution. The whole progress of the world since those early days when civilization began to take form around inland seas and waterways has moved as transportation has improved. The character and the quality of our transportation systems have been the measuring sticks of our advancing progress.

The steam railroad has made possible our wonderful twentieth century but, when we in railroading can join hands with you in the automotive industry and work together, our progress in the next 100 years is bound to be even more brilliant and marvelous than in the last century. We are a railroad-built nation. We are a United States because of the railroads. Without them this Country never could have survived as a single nation. It would have been a dis-United States, a land of petty kingdoms or republics or democracies. We are building a mighty structure here in this Country, and unless we build wisely and well the very weight of it may be the cause of its collapse. Efficient and economical distribution we must find, and this will come from the proper coordinating of the two greatest agencies to distribution, the railroads and the automotive industry. My thought is that we must make a study of the trends of traffic, the character and location of production and consumption and scientifically zone the United States, handling each part so that we can get the greatest possible efficiency of distribution, coordinating the waterways, the highways, the railways, and the airways.

As to the railroad freight-terminal itself, I can make no attempt to go into the question of the problem of the freight house, nor even the freight yard, and keep this paper within reasonable limits. Those things comprise a large subject, or a series of subjects to be considered individually. For your information and reference I have appended to this paper a list of some of the items that must be taken into consideration.

In a general way we have to consider the advisability of retaining the existing terminals as now placed and speeding up the flow of traffic through them without any large capital expenditure or of improving the present facilities or both. As against this we can plan new terminals in new locations, looking to present needs and future requirements. This last sentence really explains what I have in mind and what I want to bring before you specifically. The retaining of existing terminals as now placed, with the idea of making some improvements, does not appeal to me. It is like putting a new piece of

cloth upon an old garment. It will not work. Of course, for many reasons too numerous to mention, we who are in railroading have been doing this patching, in more than the freight terminals, in a desperate attempt to "get by."

My plan to place new freight-terminals in new locations would be impracticable under the old conditions were we depending upon horse-drawn vehicles with their limited radius of action. It can be done in this day because of the advent of the motor-truck. The tremendous advantage of the motor-truck in time and tonnage over the horse-drawn vehicle has completely overthrown our ideas as to freight-terminal locations.

Possibly now I have reached the place where a railroad man can furnish a good, legitimate reason for appearing before the Society of Automotive Engineers. To realign and relocate our freight terminals, regardless of what has been done or of the investment made, so as to render the most efficient and economical service is a tremendous undertaking. How is such a project to be financed? Can the railroads themselves be brought into agreement as to what is the wisest course to pursue? Can the very widely conflicting interests of the public be harmonized? These are very large questions, but very large returns to the benefit of all concerned are possible. The delays in switching, due to congestion, are so costly that their elimination, if only in part, would pay very handsome dividends on a very large capital investment. The one item, and an ever-increasing item, the cost of switching—nearly 40 per cent of our locomotive mileage is yard switching—suggests that the possibilities for reduction in switching charges, if our freight-terminal situation is straightened out, are large.

If we were to plan for the freight terminals of a large city of the size of Chicago yet to be built, we would not, of course, duplicate what Chicago has at the present time, or what any other city has, for that matter. Freight terminals such as those in Chicago have grown like Topsy, with the inevitable result. Chicago and other cities will continue to grow. In fact, now is the time to make our plans and to hurry their fulfillment. The longer we wait the more it will cost. In my opinion, Chicago should have outlying freight-terminals far removed from the center of the city. The exact number of miles from the center calls for careful surveys. There the long haul by steam railroads should end and at that point the motor-truck should pick up the freight. Not only should we have these terminals in the outlying districts and placed so as to take advantage of the railroad belt-lines of Chicago, but the city should be zoned for off-line stations with warehouse facilities. To point out to you the tremendous savings to the railroads and to the public in a plan of this kind hardly seems necessary. I appreciate the fact that these things offer no difficulties in simply talking about them. To make these changes in Chicago or similar ones in other cities would be a tremendous undertaking. But where we have large possibilities for tremendous savings and politics does not enter into the matter, to finance any undertaking in which the profits are self-evident generally is comparatively an easy matter.

THE TRAP-CAR SYSTEM

The trap-car situation, particularly in Chicago, presents many unfavorable aspects from almost every point of view. No justification exists for this form of discrimination except that of keen competition in the solicitation of business. By "trap-car system" I mean specifically that system whereby a shipper who has individual

RAILROAD FREIGHT-TERMINAL

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track-facilities and a platform is permitted to load his outgoing package-freight into a car that is then switched free to the freight house or transfer platform of the railroad that serves him. In the reverse direction his incoming shipments are delivered from the freight house to his platform in a car that is moved without charge to him.

Where the trap-car system is in effect, the railroad is performing a service that should be performed by a cartage company. The trap-car privilege can be given only to those shippers who have individual track-facilities. The small shipper is at a disadvantage because he must perform his own cartage and bear this cost while the larger shipper has his deliveries made free of cost to him. The cost of the trap-car service to the railroad is high because nearly all of the switching necessary to collect or deliver trap-cars must be done in congested switching-territory. The switch-engine operation to make these collections and deliveries probably is the least efficient of any operations that are performed. The railroad is at an added cost in making the transfer to and from the trap-car, and space in the freight-house setting that could be used to advantage is occupied by the cars in trap service.

Some of the items involved in the system of handling trap-cars may be of interest. On a given day, say Thursday, shipments come to the freight house from a number of widely separated points. The several lots are in as many different cars as there are originating points for the various consignments. These are unloaded from the incoming cars, trucked over the platform and loaded into the trap-car. In the evening, the trap-car is closed and taken to the yard where it is assembled in a transfer train for movement next morning to its destination. It is picked up, with other cars, by a transfer engine and moved to a siding in the vicinity of the consignee's plant. Here the local switch-engine picks it up and delivers it to the consignee's platform on Friday morning.

This seems simple enough, but let us follow the matter a little farther. The industry we are discussing is situated on Railroad B. If we follow the route of one consignment contained in the car this will answer for the entire load. This shipment was loaded at a point we will designate as X situated on Railroad A. It moved in a package freight-car to Chicago and was left in the receiving yard of the railroad on Monday. Sometime during Monday night it was switched to the transfer platform and the transfer to an interchange car was made on Tuesday. The interchange car contained a miscellaneous lot of freight for Railroad B. Tuesday evening this car went to the yard and was delivered to Railroad B but too late to go in the setting at the transfer platform on Wednesday. Thursday it was placed at the platform, transferred to the trap-car, and delivered to the consignee Friday, as already explained.

Note that the goods were switched from the yard to the transfer platform and back to the yard on Railroad A; then the interchange switching-movement between Railroads A and B was made. On Railroad B the same goods were switched from the yard to the transfer platform and back again to the yard, from which they were delivered to the consignee. Seven switch-engines were employed in the whole operation, and the goods crossed the transfer platform twice.

Assume that the car, as finally delivered, contained 8000 lb., or 4 tons of merchandise, and that the cost was \$1.25 per ton for each transfer. Various figures, running from \$14 to \$35 per car, have been given as the cost of the interchange switching-service. Assume the lower

figure and assume also, as we have every right to do, that an equal out-of-pocket cost applies to the movements between yards and platforms. We will ignore the cost of delivering the car from the yard to the consignee, although that probably will mean \$5 or \$6. Then the total out-of-pocket cost of terminal handling of the contents of the trap-car as delivered was \$38.00, or \$9.50 per ton. I would like to impress upon you that I am not giving a theoretical case but am telling you of a situation that exists. Bear in mind, too, that I am giving minimum and not maximum figures of costs. Certainly much of the package freight interchanged between railroads is costing more than we have estimated for the shipments we have followed.

Here exists a wonderful opportunity to reduce waste. The railroad tariffs do not take into consideration these terminal costs, and much of the less-than-carload lots, or freight originating in or destined to our cities is handled at a total loss to the railroads from whose lines it is shipped. Yet, while the railroad is poorer for having handled this traffic, in the last analysis the public must bear the loss. How much better it would have been had the goods been taken by a motor-truck from the freight house of Railroad A on Tuesday morning and delivered directly to the consignee. Three days would have been saved the consignee, the railroads would have saved 3 days per diem charges and they would have had \$41 more to put into their net revenue. As against this, the consignee would have been out the cartage only but he would have been placed on an even footing with his competitor who could not command the trap-car service.

FACILITIES FOR HEAVY MATERIALS

Coal-yards and facilities for other heavy material could be located at and adjacent to or in connection with outside terminals, eliminating the tremendous costs in the handling of materials of this kind. Coal, for instance, is a commodity that the steam railroads at present are hauling not only at a low rate but at a very low cost so far as the main-line haul is concerned. Some years ago I made an extensive survey and report on the methods and costs of coal handling as it related to the fuel that was being used by the railroads themselves. These costs have been reduced very materially in recent years, due to more efficient handling and also to less handling, but the cost of coal to the small consumer, or to many of the larger ones, is still high because of the cost of handling. As you know, the coal is placed in the cars at the mines in a very efficient manner but, to my mind and to a large extent, efficiency in the movement of coal ends right there.

I also made, some years ago, a careful survey and a report on the manner in which coal was handled by consignees upon its arrival at its destination, in both large cities and small towns, and I speak whereof I know, from a very intimate personal knowledge, when I say that we are wasting millions of dollars in this Country by the primitive methods by which we handle coal. Real efficiency demands that, after the coal is hoisted from the mine into the coal-car, it should be dumped thereafter and not shoveled, until it is ready for the use of the consumer. This, of course, involves a type of car that can be dumped and terminal facilities where, after the coal has been dumped, it can be dumped again; and that, when the ultimate consumer calls for the coal, it can be dumped from the coal-pocket into a motor-truck and dumped from the vehicle to the point where it is to be burned.

In an age of horse-drawn vehicles, a terminal remote

from the business center was not practicable; but, in the age of motor transport, the cost of coal handling from the mine to the consumer could be reduced tremendously by providing the proper facilities for coal storage and for handling in connection with the railroad freight-terminal. Moreover, a large saving is to be effected in the movement of coal by motor-truck from the terminal to the consumer. This cannot be accomplished by having dozens of coal companies each operating its own fleet of trucks out to the terminals, because that is immediately a question of a one-way haul. To handle this coal movement by motor-truck efficiently and economically calls for its handling by one cartage-corporation which, because of its size, could furnish not only prompt service and do it economically in the hauling of that special commodity, coal, but which, because of the size of its undertakings, might lessen the one-way-empty haul by taking manufacturers' products to the freight terminal and returning with the load of coal. The automotive industry is giving, I know, careful consideration to demountable-body equipment, it is developing the tractor and trailer, and its progress merits only praise. I can only suggest the intensive study of the freight-terminal problem in all its details as they relate to the motor-truck. Each item is more or less a law unto itself and therefore it must be studied carefully before attempting to meet the requirements with existing types of motor-transport equipment.

In railroading, we have learned to our sorrow the cost of the empty haul in which, for every two cars we move loaded, we are moving one car empty. This is due in part to the irregular flow of traffic and to seasonableness of shipments and also to their character. I appreciate the difficulty of designing a motor-truck that can be utilized successfully for any and for every class of commodity. We have wrestled with this question of a utility car in railroading for many years, and we are still compelled to build refrigerator-cars, poultry-cars, flat cars, and a variety of box and coal-cars to say nothing of the number of specially built freight-cars.

I have spoken of the movement of coal, as it seemed an apt illustration of what might be accomplished in the way of savings through the correct locating of railroad freight-terminals. What is true of coal is true of any dumpable material, and with material of this kind a large percentage of the final cost is found to lie in the handling. L. F. Loree, president of the Delaware & Hudson Railroad, has stated that the average trip of a freight-car is 14.90 days and that, of this, the road haul is only 1.64 days. To elaborate upon this is hardly necessary, since it is a strong enough statement in itself, but it certainly does emphasize the need for the elimination of the railroad freight-terminal costs. Not that they will all be eliminated under the plan of utilizing an outside terminal, because to operate motor-trucks costs money and the motor-truck would have to pick up the work that is now being done in the terminal.

FREIGHT CONGESTION IN CITIES

I cannot take the time to refer to the congestion in a large city like Chicago which is brought about by having our freight terminals wrongly located. Neither do I want to refer to any one railroad and, in mentioning the Illinois Central I do so only because, as I dictate my thoughts about the matter, I am constantly looking at the freight yards of this railroad as I see them from my office window. Here they are, located on the most valuable land in the entire city and this, by the way, but suggests the profit to this railroad in exchanging this

valuable land for cheaper land farther out. But the point I want to make right here is that every pound of freight that goes in and comes out of this terminal must go through the most congested part of Chicago during its delivery. Regardless of the nuisance to the citizens of Chicago, the waste in time which, of course, is money, is tremendous, in having this haul made from this particular location through the congested district, but I hasten to say that this is no criticism whatever of the Illinois Central.

Another thing in connection with freight terminals located in an outlying district, which appeals to me very strongly, is the building up for the railroad employee a city of his own adjacent to his work. The cost of such land would be small compared with any other property that he might buy for a home. The employing corporation could arrange to get it for him at cost, and I believe the advantages of this are so apparent as to make elaboration of this point unnecessary.

I know that I have touched on but very few of the high spots in connection with the railroad freight-terminal. I have endeavored, however, to emphasize the importance of the locating of freight terminals.

RAILROAD SUPPLIES AND EQUIPMENT

Thus far I have talked from my experience in railroading, but now I speak from a basis of about 15 years spent in the railroad-supply manufacturing-business, in special work for over 30 leading railroad-supply manufacturers. Out of this experience let me say to you that railroads demand much from the manufacturers from whom they purchase materials and equipment. The railroad-supply manufacturers constitute, in fact, the research laboratory for the railroads. That the railroads have cooperated in this work is shown by the many associations that have been studying various problems of equipment for many years. But in the last 20 years especially, since Government regulation has become so drastic and all-inclusive, the railroad man has been compelled to spend more and more time at hearings and less time in the running of his railroad. He has come to depend more and more upon the railroad-supply manufacturer who, uptodate, has not been regulated. The builders of locomotives and the manufacturers of locomotive specialties work out the finished locomotive for the railroads. The same is true of cars, both passenger and freight; the building of shops and engine-houses is turned over to specialists and not only does the railroad official depend upon the railroad-supply manufacturer for cars and locomotives and other equipment, but he calls upon him for service in the operation of such equipment. In recent years, the service staffs of railroad-supply manufacturers have become a veritable army which almost literally patrols the thousands of miles of the main trackage of the steam railroads to keep constantly in touch with railroad equipment and facilities and to spend countless days in the instruction and training of railroad employees. I mention this particularly because, if there is any one point that I want to impress upon you, it is that the railroads need the expert help which the members of the Society of Automotive Engineers can give them. Perhaps you may feel that the problem of the railroad freight-terminal is not for you to solve; but I feel very strongly that it is very much your business. The motor-truck is the key to the whole situation. Were it not for the advent of the internal-combustion engine and its application to vehicles, the suggestions that I have made in regard to the proper locating of freight terminals would hardly be worth the making.

Following the established precedent in railroading and its relation to railroad-supply manufacturers, I say that the automotive industry should solve the problem of the railroad freight-terminal because it has, in the motor-truck, the large part of the answer to this problem. Automotive engineers must acquaint themselves with railroad conditions and with the handicaps, more than with any other business, because they have a very large handicap of political interference. You cannot go to the railroads and say to them: "Your terminal operation-costs can be lessened very greatly by the use of motor-trucks," and offer them motor-trucks out of stock.

Coordinated transportation-interests should control the motor-trucks operating within the terminal district. It is the only way in which we will get efficiency, economy and service. The railroad man must wake up to the fact that railroading of the future will be off the rails as well as on the rails, and the time must come when the railroad has expanded into a transportation company that picks up a commodity at one door, takes it on a 1000-mile haul and delivers it at another door. In my opinion, the question of the ownership and control of the motor-vehicle service, both within and outside the terminal, is still debatable and cannot be answered properly in the light of the experience we now have. The location of freight terminals of the future will be dependent upon motor-truck operations and on how well the automotive industry adapts its equipment to this operation and to the elimination of the economic waste of down-town terminals and trap-car movements.

WORK THAT THE AUTOMOTIVE INDUSTRY SHOULD DO

I want to leave with you some definite and concrete thought as to just what the Society can do with the great problem of transportation. The big accomplishments in transportation thus far are to the credit of the operating officials of the railroads. The Society should study carefully the needs of the freight-terminal, and I do not doubt but that it has done so. It should put before the railroads as a whole, in any given section like Chicago, the results of its studies and surveys, and railroad and motor-truck facilities should be coordinated in order that distribution can be accomplished with the least cost in time and in money. The proper railroad official knows transportation; he knows the flow of traffic and the needs of the communities. When some far-sighted manufacturer in the automotive industry can join hands with the railroads in any given territory in the ownership and operation of the motor-truck, the coordinating of the steam railroad and motor transport will have been accomplished to the benefit of the public and for the profit of the transportation company.

Looking at the problem from the viewpoint of the railroad man, I think that motor transport offers to steam railroading some very wonderful opportunities in economies and in greater efficiency. This, naturally, will be tremendously advantageous to the shipper and means added service for the public. I feel most strongly that the day has arrived when we must, as railroad men, railroad off the railroads as well as on. I mean by this that railroading must mean transportation. It must mean the moving of freight and passengers in the way that furnishes the very best service. The railroads must go farther than simply to receive freight at some point on their lines and move it to some other point on the rails. They must take the commodity, whatever it is and wherever it is, and move it on the rails or off of the rails and deliver it at the point where the consignee can make immediate use of it. Railroad men know the transporta-

tion game. The shipper and the consignee are not supposed to be experienced in transportation; their activities lie in another field of endeavor.

I also wish to emphasize to the Society the fact that a tremendous field awaits the automotive industry in helping the steam railroads and the electric railways in solving the problems of transportation. May I suggest that the monetary rewards to the automotive industry in doing this are far beyond anything that it has yet received. Railroad passenger-earnings are small as compared with the freight earnings in railroading. You, as members of the automotive industry, have been providing motorcoaches and automobiles for private ownership. This is comparable to the passenger service on a steam railroad. You have done very little in the building of trucks and the moving of freight, and yet here is a field in which your opportunities are the largest and the returns are tremendous, far beyond anything that you have ever received in the building of vehicles for the transportation of persons.

Looking at the whole subject from the viewpoint of the railroad man who, of course, has had his largest experience in transportation problems, I say to you of the automotive industry that you are just entering the field of transportation. A very wonderful opportunity awaits you, not only in benefiting yourselves, but in giving an added transportation service to the people of this Country which shall have a very real effect upon the acceleration of our societal progress.

APPENDIX

Following is a list of some of the items which must be taken into account in considering present and prospective freight-terminals:

A—Less-than-Carload Freight-Terminals. Present Location

- (1) Present freight-houses usually are in congested territory because they were located when the city was smaller and horse-drawn vehicles of limited radius of action were used for cartage
- (2) In general, they are on high-priced land
- (3) In most instances they are situated in territory where switching is heavy
- (4) They are generally at points where the cartage must pass through streets having the densest traffic
- (5) One of the fundamental reasons why many freight houses are situated as they are is that their original locations were determined by the necessity of interchanging freight between rail and water transportation-facilities.
- (6) Usually they are near the retail district and are not adjacent to the manufacturing districts in which large quantities of package freight originate
- (7) For the same reason that they are distant from the center of origin of much package freight, they also are at a distance from the final destination of much of the incoming freight.

B—Freight-House Operation

- (1) Frequently, freight-house forces are not well organized
- (2) The supervision frequently is inadequate and sometimes is not of very high quality
- (3) Many freight houses have a poor system, or no system, of designating doors for the delivery or the acceptance of shipments
- (4) For this reason, many freight houses are afflicted

with congestion on the driveways and at the doors

- (5) Many freight houses have a poor or a loose system of checking lots delivered for shipment
- (6) Also, many freight houses have a loose system of checking to whom and when deliveries of incoming freight are made
- (7) In many instances, inefficiency exists in the trucking on the freight-house floor
- (8) Great inefficiency has been found in the present system of cartage to and from freight houses

C—Platform Costs

- (1) The platform costs of handling package freight, at both the transfer platforms and on the freight-house floor, generally are too high because lack of space causes floor or platform congestion
- (2) Other causes of excessive costs are poor organization, poor supervision and loose methods
- (3) In many freight houses in Chicago, the custom of placing tunnel cars on the freight-house floor adds to the difficulty of freight-house operation and thereby increases the platform cost
- (4) Few if any railroads have adopted the bonus system of paying freight-house labor. A considerable increase in efficiency could be made by the bonus system alone

D—The Trap-Car System

- (1) This system gives free service for collection and delivery of less-than-carload package freight to large shippers
- (2) On the other hand, small shippers do not have this service and therefore are at a serious disadvantage as compared with large shippers
- (3) Trap cars usually are handled at a loss to the railroad

E—Losses to the Railroad on Less-than-Carload Freight

- (1) The railroad must haul its package freight from 152 to 350 miles from the point of origin to break even on less-than-carload business. As a great volume of package freight is destined to points less distant than these limits, the business is handled at a dead loss

F—Interchange of Less-than-Carload Freight between Railroads

- (1) A heavy cost is applicable to package freight, due to the cost of platform labor in making transfers
- (2) The present system of interchange by switching ties up a large number of cars that might otherwise be in productive service
- (3) The cost of interchange switching is high
- (4) Delays under this method of interchange are enormous, to cars and to shipments
- (5) The present method of interchange adds to the congestion of freight terminals because of the necessary switching
- (6) The present method is inefficient because the motive power required in interchange movements is not used to capacity
- (7) In Chicago, the system of one-way loading of power in interchange service reduces the efficiency about 50 per cent

G—Delivery of Less-than-Carload Freight to Secondary Stations

- (1) Where a railroad maintains a main and one or more secondary stations at a terminal, two methods of switching freight to the secondary station are used
- (2) Some railroads have a transfer platform at some point outside the terminal, where package freight is segregated for the several destinations

- (3) In such cases the receipt of the package at the secondary station is delayed, due to the time necessary for it to pass over the transfer platform
- (4) Every transfer platform ties up cars while the transfer is being made. This system adds to the switching at the terminal
- (5) This system requires too many handlings of the freight
- (6) The revenue received from the freight is decreased by the amount representing the cost of the transfer
- (7) Other railroads use what is known as the "inside transfer"; that is, the package freight is sent to the main freight-house where it is reloaded into ferry cars for movement to the secondary station
- (8) All that has been said about the undesirability of the outside transfer can be said of the inside transfer, in addition to which a return haul on the cars usually is necessary

H—Remedies That Can Be Applied To Cure the Present Troubles

- (1) Revision of the present facilities does not supply a solution of the problem
- (2) The present facilities should be moved to points farther out and revised completely. Removal to points farther out will release the high-priced land for the expansion of other facilities or for purposes that will be of benefit to the railroad
- (3) Land at the point where new terminals should be situated usually can be acquired at a fraction of the value of the land now occupied
- (4) Inland stations should be a part of the new freight-handling system and these should be placed at strategic points where large volumes of package freight originate or must be distributed
- (5) Inland or universal stations for the collection and distribution of package freight will require the use of motor-trucks between the rail station and the off-rail stations
- (6) Interchange between railroads should be made by motor-truck to eliminate the most undesirable form of switching service.
- (7) Deliveries and collection of all freight can be made by motor-truck

I—Inland or Off-Rail Universal Stations

- (1) Such stations should be situated close to the point of origin of package freight and, so far as possible, near the center of distribution of incoming freight
- (2) Such stations permit full truck-loads to be hauled because the collection at the inland station is made from a large number of shippers whose shipments can be consolidated to make full loads for haulage to the rail-head station
- (3) By placing inbound and outbound platforms at separate levels, any confusion or cross movement of trucks can be avoided
- (4) Inland stations, with the on-rail station at some distance from the center of the city, permit routing of the cartage around the congested districts and on streets where congestion does not exist
- (5) They permit more efficient haulage, not only because the trucks can travel with full loads, but also because the truck-mileage is reduced materially
- (6) A system of inland universal stations permits more prompt release of freight-cars at the rail-head station and thereby saves many thousands of car days every year

RAILROAD FREIGHT-TERMINAL

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- (7) The elimination of such delays reduces the per diem cost on cars
- (8) For the same reason, delays to the shipments are reduced very much
- (9) Inbound cars can be loaded more nearly to cubical capacity, because they will all be destined to the same on-rail station
- (10) Such a system eliminates all the freight-house switching in the congested district and reduces that necessary at the outside railroad station, because all cars can be loaded to this station indiscriminately and the interchange between railroads and the haulage to the off-rail station can be made by motor-truck
- (11) The system of inland stations makes store-door delivery possible
- (12) An inland station should have a loft building as an adjunct
- (13) The warehousing that will be attracted should make the individual station self-supporting
- (14) Another item is the fact that large jobbers who require more warehouse space than would likely be available in a loft building of this character can locate their own warehouses adjacent to the inland station, or even across the street from it, and make deliveries to the outgoing platform by mechanical carriers
- (15) In some instances manufacturers or jobbers will desire to take space in the loft building to display their wares
- (16) Also, an advantage accrues to the shipper, where a system of inland stations is maintained, because it shortens his haul in both directions
- (17) He can load all outgoing shipments or all incoming shipments on one motor-truck. This gives greater efficiency to his trucks and thereby reduces the number of trucks required to handle his business
- (18) For the same reason, the shipper's cost of cartage is reduced.
- (19) Where inland stations are maintained, both the size of the shipping rooms of the shipper and his shipping-room force have been reduced
- (20) The cartage between the on-rail station and the off-rail stations should be handled with tractors and trailers rather than by the usual form of motor-truck
- (21) This system reduces the freight-house cost of the railroad, because shipments move directly from car to trailer without the necessity of placing them on the freight-house floor
- (22) The investment in freight-house facilities is reduced materially and the transfer platform that is adjacent to a great many freight houses is not necessary
- (23) Because freight can move directly across the freight-house floor without stop, the freight-house operation is improved and the floor and the platform costs are reduced materially
- (24) Where inland stations are maintained, it has been found that a material reduction in claims for loss and for damage is effected

J—Interchange between Railroads

- (1) The interchange of less-than-carload freight between railroads should be made with tractors and trailers
- (2) Such a system
 - (a) Materially speeds up the interchange movement
 - (b) Permits cars to be released promptly
 - (c) Reduces freight-house costs
 - (d) Reduces per diem costs
 - (e) Eliminates, in part, transfer platforms

- (f) Reduces the investment in the terminal freight-facilities
- (g) Better freight-house operation
- (h) Reduces claims for loss and damage
- (i) Gives greater capacity to cars

K—How Motor-Truck Delivery and Interchange Should Be Handled

- (1) The first is by contracting with an outside organization having no connection with the railroad.
- (2) The second method is to organize a separate corporation under railroad ownership
- (3) In both cases, however, the cartage operation should be divorced entirely from the railroad operation

L—The Reason for the Foregoing Methods

- (1) Railroads are organized for rail operation only
- (2) The personnel of the railroad knows nothing about motor haulage
- (3) It does not understand the peculiar organization necessary to operate motor transport
- (4) Its mechanical forces are not organized for motor-truck maintenance and whether a separate department would be possible or desirable is doubtful
- (5) Railroad men in general do not understand the psychology of motor transport
- (6) Few railroads will undertake to supply the kind or the quality of supervision necessary
- (7) Railroad men in general do not have commercial instincts, and motor transport should be classed as a commercial proposition
- (8) When revenue begins to drop, railroad officials are inclined to make arbitrary reductions without a proper study of the situation
- (9) Such a system of management would be fatal to any form of motor transport
- (10) A bonus system seems to be necessary to secure full efficiency on the part of the men engaged in the operation of motor transport, and this system would be difficult for the railroads to apply
- (11) Railroad organizations are peculiar to themselves but are semi-military. They do not have the flexibility of a commercial organization
- (12) For this reason, and also because they are designed primarily to handle rail transport only, they probably could not handle motor transport efficiently
- (13) Railroads cannot go into warehousing projects except, possibly, through subsidiary corporations
- (14) That any motor-transport operation put under the operating officials of a railroad who are not acquainted with this form of transportation would fail is fairly certain
- (15) That the tendency would be to try to make the motor-transport department fit in with the present rail organization is also reasonably certain
- (16) On the other hand, if the motor-transport department is organized as a separate department, continual bickering between departments is likely to occur

M—Disadvantages and Difficulties

- (1) A large capital investment is necessary to make a material change in the present form of freight terminals
- (2) Before a system of inland universal stations and the removal of present freight houses to outlying points and the handling of freight by motor transport can be brought about, many

- interests must be brought together. This includes the shippers, the cartage interests, municipal authorities, and the public, as well as the railroads themselves
- (3) On the part of the shippers and railroads such a project is likely to be met with inertia. To change preconceived notions is difficult. The present form of freight terminals has been in existence for so long and the present methods of handling freight have become so routine in character that considerable reluctance to change probably will be encountered, in addition to the fact that both shippers and railroads are always reluctant to try a new idea
 - (4) The opposition on the part of the shippers, at the start, probably will be more active than that on the part of the railroads; but because the railroads will see the necessity of a large investment, they probably will be harder to move
 - (5) A complete change in operating methods will be necessary on the part of the shippers and on the part of the railroads
 - (6) If the freight houses are moved to outlying points, some instances are probable where the railroads will not be able to put the land upon which the present facilities are situated to immediate use, and they will be reluctant to undertake an investment that will result in having the high-priced land lie idle
 - (7) A change as radical as that suggested should not be made without long and intensive study and complete consideration of all the matters involved
 - (8) A period of rather intensive education will be necessary, covering all the interests involved
 - (9) The railroads might feel that commercial interests are back of such a movement and that the agitation is in the interest of the agitators and not in the interest of the railroads. Probably the railroads might also feel that some advantage might be obtained by their competitors which they do not now possess
 - (10) Probably the same feeling will exist on the part of the shippers
 - (11) This probably will be true particularly of those shippers who now have advantage of the trap-car. They certainly will be reluctant to eliminate the advantage that the trap-car gives them
- N—What Must Be Considered in Designing a Freight Terminal*
- (1) The land available
 - (2) Its situation with reference to operating efficiency
 - (3) The source and availability of labor
 - (4) The effect of the terminal operations on the persons living in the vicinity
 - (5) Study of the operations to be performed
 - (6) The proper track layout to accomplish the results desired
 - (7) The quantity of grading necessary and the source of the grading material
 - (8) The yard equipment which includes the track appliances such as rails and fastenings, ties, frogs, switches, switch stands, quarters for track tools, hand-cars, and push-cars; mechanical equipment such as derricks or locomotive cranes; engine-terminal, car-repair, coaling, cinder disposal, water supply, power-plant, and icing facilities; yard offices and communication equipment such as telephones, pneumatic tubes, messenger service, loud speakers, teletype, and telegraph; classification switching; engine, yard and road dispatching; the handling of waybills; an accounting system and yard check; yard lighting and snow removal in the northern section of the Country; present and prospective volume of traffic; fluctuations in traffic; character of traffic; direction of heavy traffic; and type of power
 - (9) If "hump" yards shall be included as part of the plan, car retarders, scales, distribution of hump-yard forces, power or manual handling of switches, and proper grades to establish should be considered and, if located in a cold climate, whether a mechanical hump is desirable
 - (10) In arriving at a decision as to the method of operation, the fact that steam switching-locomotives are uneconomical under the present system of operation must be considered
 - (11) Such locomotives are used intermittently and at low efficiency
 - (12) They do not work at capacity on account of partly loaded cars
 - (13) Their standby losses are high
 - (14) Intermittent service under variable loads makes firing difficult, and air pollution from smoke and cinders is difficult to control
 - (15) Many present-day switching-locomotives are of obsolete type and should be replaced in any event
 - (16) Forty per cent of the total engine-mileage on the railroads of the Country is made in yard switching; therefore, every device or method of operation that will reduce yard switching is of inestimable benefit to the railroads
 - (17) Consideration of whether a transfer platform shall be included in the plan and is necessary and, if so, whether it shall be a separate facility or a part of the general scheme
 - (18) What mechanical appliances or equipment shall be provided at freight-house and at transfer platforms. So far, power-operated trucks with trailers and lifting trucks seem to be about the only equipment that has withstood the test of platform demands
 - (19) The proper placing and capacity of scales on the freight-house floor is a matter in which excellent judgment is required
 - (20) Whether any change in the ordinary freight-house layout can be made with a view toward reducing the volume and distance of trucking must also be considered

GASOLINE ENGINES IN CONSTRUCTION FIELD

A SURVEY by *Engineering News-Record* shows a surprising demand for gasoline engines in the construction field. The report indicates that the construction industry buys annually 57,300 gasoline engines as powerplants for portable equipment, exclusive of motor-trucks and tractors, and the larger stationary-gasoline-engine installations in waterworks or sewage pumping plants and lift or swing draw-bridge service. For portable construction equipment, the sizes of engines varied from 1½ to 150 hp., with indications that the aggregate capacity of a year's purchases of

gasoline engines for use in construction work exceeds 1,000,000 hp.

About 25 per cent of the total number of gasoline engines bought by construction men in the course of a year is taken by the concrete-mixer industry alone. The 13 member companies of the Mixer Manufacturers Bureau of the Associated General Contractors bought for installation as the power units of their building and paving mixers, a total of 15,200 gasoline engines in 1925. These ranged in size from 1½ to 47 hp., and in type from one to four-cylinder units.—*Class.*

Wasp and Hornet Radial Air-Cooled Aeronautic Engines

By GEORGE J. MEAD¹

AERONAUTIC MEETING PAPER

Illustrated with PHOTOGRAPHS

ABSTRACT

DECISION that the fixed radial air-cooled type of aeronautic engine offers the most possibilities in light weight and maximum dependability was arrived at by the company with which the author is connected after a careful and comprehensive engineering analysis of many types of both water-cooled and air-cooled engine and therefore it undertook the development of this type. Because the Navy was desirous of obtaining a 400-hp. direct-drive engine and a 500-hp. engine to drive either direct or geared and because a commercial air-cooled engine to replace the Liberty-12 water-cooled engine was desirable owing to the increased pay-load it would make possible, it was decided to undertake first the development of a 400-hp. engine of this type.

Work on the design was started Aug. 1, 1925, and the first engine was finished on Dec. 24, or approximately 5 months later. This engine was named the Wasp. In the winter of 1925 and 1926 work was started on a 500-hp. engine of almost identical design, and the Hornet engine was ready to run early the following June. The design of these engines is characterized by high cooling-efficiency, high mean effective pressure, low fuel consumption per horsepower-hour, light weight, high power-output, rigidity and strength of crankcase, maximum accessibility of parts and accessories, easy demountability of crankcase and cylinders from the accessories assembly, and complete protection of the accessories between the crankcase and the fire-walls of the fuselage.

Unique features include a solid one-piece master connecting-rod without split big-end, a two-piece crankshaft, a vertically divided crankcase formed of two large identical aluminum forgings, assembly of the power end and accessory end in two units, driving all the accessories from the main shaft by three lay-shafts through large spur-gears, distribution of the fuel mixture from a double carburetor by a high-speed impeller through separate tangential pipes to the individual cylinders, the casting of boxes enclosing the valve rocker-arms integrally with the cylinder-heads, large size of the valves and ports, and hemispherical combustion-chambers and concave piston-heads.

Bore of the cylinders and stroke of the pistons are equal. The required guaranteed power is calculated on a basis of 1344-cu. in. displacement and 125-lb. mean effective pressure at 1900 r.p.m. Provision was made for an over-speed of 2400 r.p.m. to be attained in a dive. On standard straight fuel a mean effective pressure of 130 lb. is obtained with zero pressure in the intake system, and 140 lb. has been developed consistently with 30 per cent of benzol or its equivalent. To operate the engines on straight aviation-gasoline at their rated power with a fuel consumption of 0.48 lb. per hp-hr. has been found possible.

Test flights of the Wasp in fighting airplanes designed for water-cooled engines developed high speeds equal to those made with the original engines and demonstrated a materially better rate of climb and

lower landing-speeds. The air resistance seems less than that of a water-cooled engine with its radiator. As experience with air-cooled powerplants accumulates their superiority should be even more evident.

THIS is an era of specialization, and aviation is no exception to the rule. As in the case of other industries, the greatest progress in aviation is possible by specialization. Our policy from the start has been to specialize, not only in powerplants but in powerplants of a single type. After a careful and comprehensive engineering analysis of practically all types, coupled with extensive experience during the last 10 years in the design, construction and operation of both water-cooled and air-cooled engines, we decided that the fixed air-cooled radial type offered the most possibilities. This type makes available the maximum dependability with the lightest powerplant. The low powerplant-weight per horsepower gives the best possible airplane performance, and airplane performance is the most important measure of an engine.

Having decided upon the radial type, it was next necessary to determine upon the power size. We were

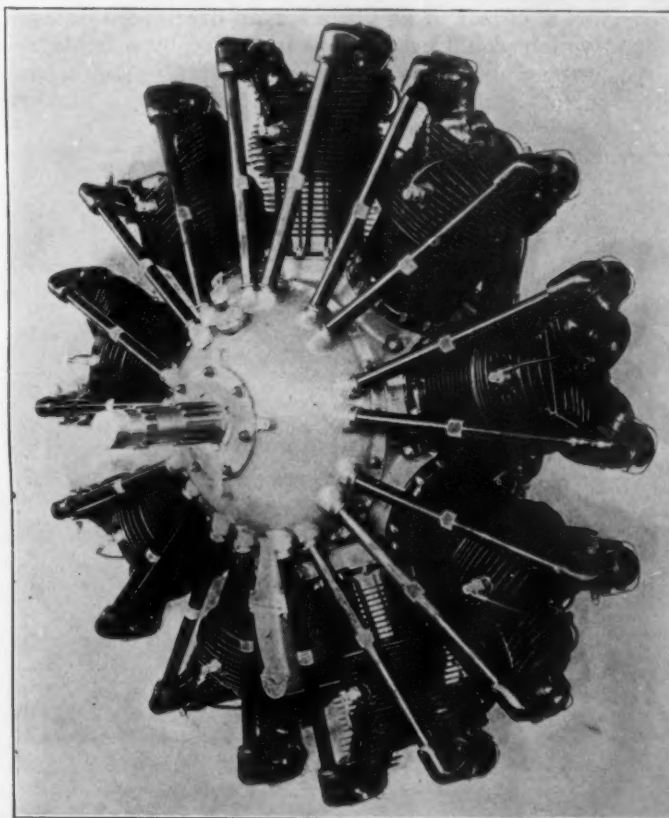


FIG. 1—PRATT & WHITNEY RADIAL AIR-COOLED 400-HP. WASP ENGINE
This Three-Quarter Front View Shows the Hemispherical Crankcase
Nose Section, Enclosed Valve-Operating Mechanism and Splined
End of Crankshaft for Mounting the Propeller Hub

¹ M.S.A.E.—Vice-president, Pratt & Whitney Aircraft Co., Hartford, Conn.

guided in this decision by the military as well as the commercial requirements. The Navy Department, following its established policy of developing three radial engines to take care of all the Navy requirements; namely, 200 and 400-hp. direct-drive units and a 500-hp. engine to drive either direct or geared, was anxious to obtain a 400-hp. engine. Commercially, an air-cooled engine was highly desirable to replace the Liberty-12 engine on account of the increased pay-load which it would make possible. That an efficient 200-hp. air-cooled radial engine had quickly and easily displaced an extremely reliable water-cooled engine of the same power, not only in military service but in commercial operations as well, was significant. Under these circumstances we decided to develop first an engine of 400 hp., which is now known as the Wasp. This is shown in Fig. 1.

The first consideration in designing this new engine, after the determination of the type and power, was the piston displacement. This depends upon the power required, which, in turn, involves the crank speed and mean effective pressure. High crank-speeds are necessary for light weight per horsepower. To date, no radial engine has had a service operating-speed of more than 1800 r.p.m. The mean effective pressures have been relatively low; 120 lb. was regarded as good. We decided that the required guaranteed power could be obtained with 1344-cu. in. displacement on the basis of 125-lb. mean effective pressure and 1900 r.p.m. This meant that the average engine must be capable of at least 420 hp. or 130-lb. mean effective pressure to assure a safe margin above the guarantee.

Another factor that must be considered in this connection is the kind of fuel to be used. With proper cylinder and intake conditions, the detonating property of the fuel definitely limits the brake mean effective pressure. Provision also had to be made for an over-speed of 2400 r.p.m., which would be attained in a dive by a fighter.

The proper proportions of bore and stroke were next given serious consideration. In a radial engine a number

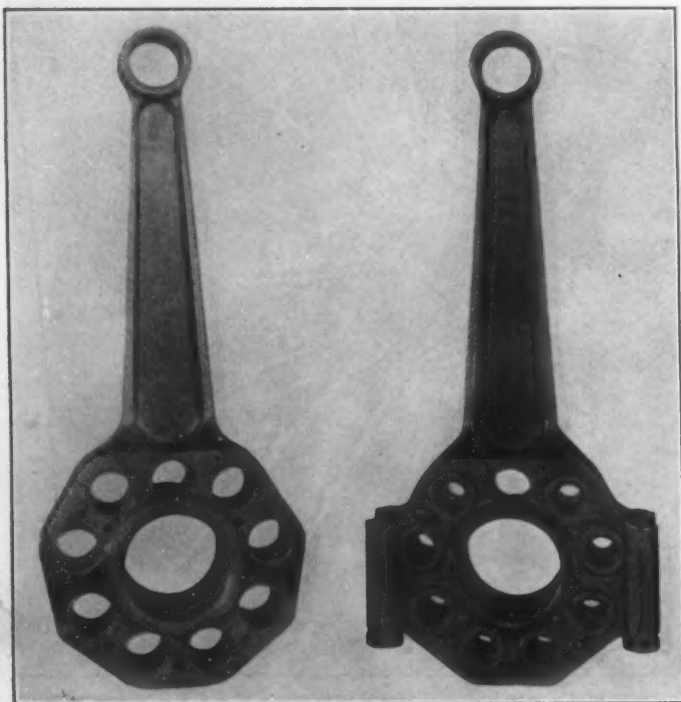


FIG. 2—SOLID AND SPLIT MASTER-RODS
The One-Piece Connecting-Rod at the Left Is Used as It Is Lighter, Stronger and More Rigid than the Split Type at the Right

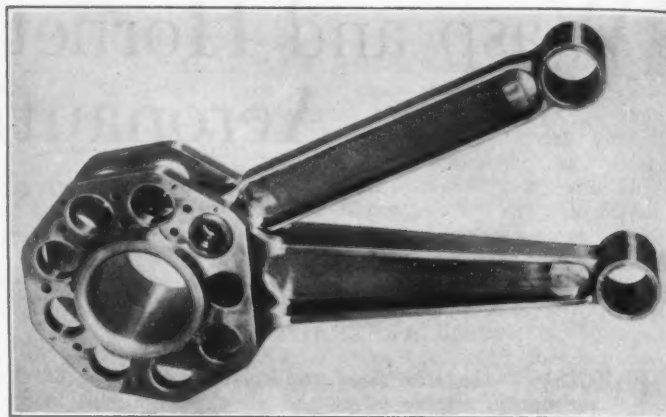


FIG. 3—MASTER AND LINK CONNECTING-ROD
Seven Other Rods Are Pinned into the Hub Like the One at the Left. The Big-End Bearing of the Master Rod Consists of Two Flanged Babbitt-Lined Steel Shells Pressed into the Rod

of particular limitations must be considered, such as cylinder and valve cooling, link-rod angularity and overall diameter, in addition to the usual considerations, such as proper valve and port sizes, weight of reciprocating parts and the like. We prefer what is known as a square engine, that is, with bore and stroke equal. This proportion provides the best cylinder-cooling, moderate connecting-rod angularity and the minimum diameter as well as the requisite room for large valves and ports. With these specifications determined, studies were made of the detail-design problems involved.

SIMPLE ONE-PIECE CONNECTING-ROD USED

To produce a really light engine, provisions obviously must be made for high crank-speeds as well as high power-output. From our experience, the design of the master connecting-rod was the limiting factor. Heretofore standard practice has been to use a rod with a split big-end, as seen at the right in Fig. 2. This construction has two serious defects. Owing to the stepped split, the rods were likely to crack through the step and adjacent knuckle-pin hole. Due to the wide spacing of the four clamping bolts, distortion occurs in the cap, and this produces bending stresses in the bolts, either breaking them or splitting the bolt bosses. Added weight in the master rod could not be considered, as any weight added to the mass rotating on the crank-pin must be balanced by approximately its own mass on the counterweights. In 1919 I worked out a solution of this problem but for another purpose. At that time, while engaged in the design of the first large radial engine used by the Air Service, it was very desirable to provide for as nearly ideal big-end bearing conditions as possible, hence a solid master-rod, as at the left in Fig. 2 and in Fig. 3, was used with a two-piece shaft. This construction provided for the rigid support of the big-end bearing, which consisted of two flanged babbitt-lined bronze shells pressed into the rod. These bearings were eminently satisfactory. When faced with the problem of high crank-speeds, we turned again to this construction, which was obviously ideal, as it not only overcame the rod weaknesses but provided the best possible bearing conditions for the high power-outputs now required.

CONSTRUCTION OF TWO-PIECE CRANKSHAFT

The problem might then be said to have simply been shifted from the rod to the shaft. However, to develop an entirely satisfactory shaft that is as rigid as a solid shaft and still can be disassembled with ease, was pos-

sible. This two-piece crankshaft, as shown assembled in Fig. 4, has the crankpin integral with the forward part of the shaft, which also carries the propeller hub. Thus the power is transmitted from the master rod to the propeller through a solid shaft. The rear portion of the shaft telescopes into the crankpin and is carried completely through it. The proper angular relation between the two parts of the shaft is maintained by splines, and a long through-bolt is used to unite the two parts as well as to jack them apart. The shaft is carried on three antifriction bearings, two of which are NKA roller bearings located close to the crank cheeks while the third is a deep-row ball-bearing immediately behind the propeller. This ball-bearing takes the propeller thrust as well as the radial load.

Owing to the two-piece construction, to extend the crank cheeks to provide a very substantial means of attaching the counterweights is possible. Our original calculation considered these webs only for centrifugal loading and for stresses due to acceleration and deceleration in the plane of the weights. From recent experience, however, to provide for gyroscopic forces imposed by extremely rapid airplane maneuvers also has been found necessary. To each web is attached a counterweight consisting of two steel sectors notched to fit over the

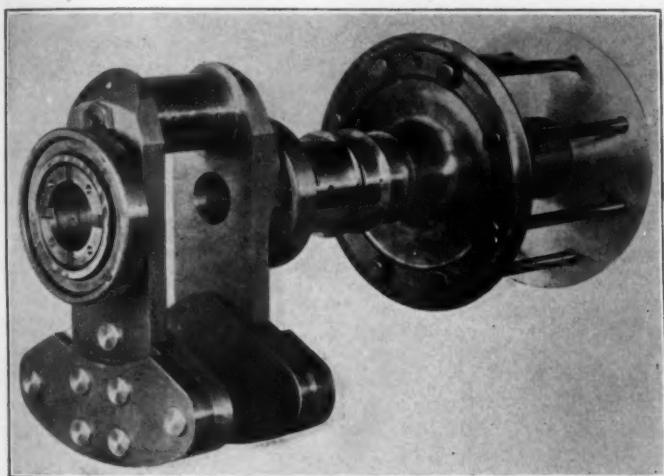


FIG. 4—CRANKSHAFT AND PROPELLER-HUB ASSEMBLY

The Crank-Pin Is Integral with the Forward Part of the Shaft and Power Is Transmitted through a Solid Shaft from the Master Rod to the Propeller. The Rear Portion of the Shaft Telescopes into and Completely through the Crank-Pin and Is Held by a Through Bolt. Two Roller-Bearings Are Mounted Close to the Crank Cheeks and a Third Directly behind the Propeller Hub Takes Both the Thrust and Radial Load of the Propeller. The Crank Cheeks Are Extended and Counterweights Attached To Equalize All Unbalanced Forces

web, which is flared-out at the outer end. In this construction the flare holds the weights on while the mortising prevents their skewing on the crank web. It is well to point out here that the radial-type engine is perfectly balanced dynamically. All the unbalanced forces can be equalized by proper counterweights. In our case, this fact, combined with the use of the short large-diameter crankshaft that entirely eliminates any torsional vibration and gives excellent distribution, results in a very smooth-running engine.

ALUMINUM CRANKCASE FORGED IN HALVES

Rigid crankshaft support was absolutely necessary. The open-end cup-shape type of case with one main bearing carried in a loose plate was entirely unsuited for this purpose. Moreover, we wanted a case of such simple design that uniformly strong parts could be obtained in production. The solution of this problem was a forged

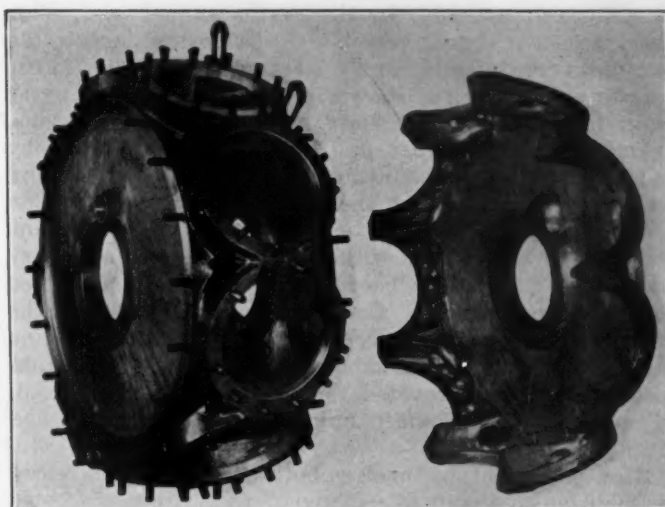


FIG. 5—FORGED ALUMINUM CRANKCASE

Each Half Is Made as a Large Forging, as Shown at the Right, and the Two Identical Forgings Are Held Together by Nine Through Bolts. The Result Is a Light Construction in Which the Crankshaft Load Is Divided Equally between the Two Main Bearings So That Working between the Two Crankcase Sections Is Obviated

aluminum crankcase, which is shown in Fig. 5, consisting of two identical pieces facing each other and held together by nine through bolts, one between each two cylinders. This construction is both extremely strong and very light. Moreover, the load is divided equally between the two main bearings and consequently no working occurs between the crankcase sections. The nose section is hemispherical and consequently very rigid and strong. It carries the thrust-bearing and the valve-tappet guides.

Two rear sections, the blower and the rearmost sec-

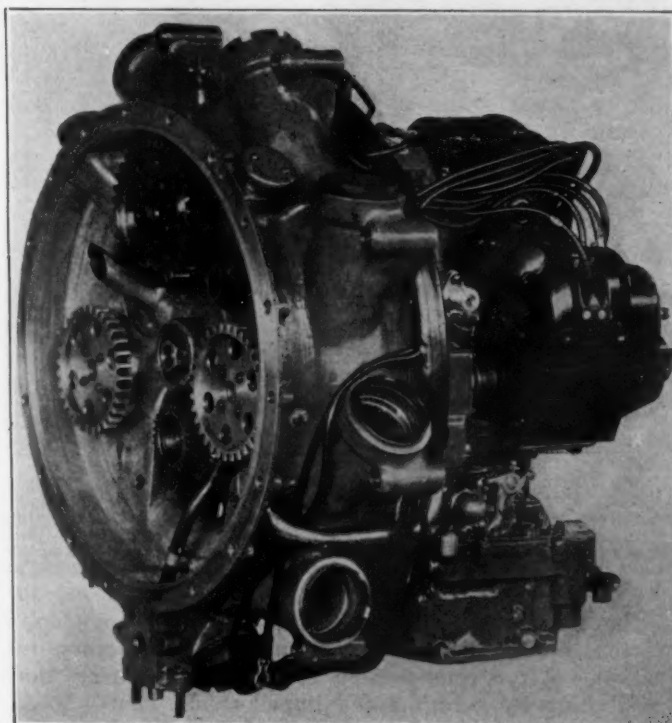


FIG. 6—ACCESSORY ASSEMBLY OF WASP ENGINE

This Consists of a Blower Section That Bolts to the Rear of the Crankcase and a Rear Section That Carries the Starter, Magneto, Carburetor, and Other Accessories. For Service Work or Other Purposes the Crankcase with Its Cylinders, Compromising the Power End of the Engine, Can Be Removed Without Disturbing the Accessories Unit. The Three Spur-Gears Shown Mesh with the Gear on the Crankshaft and Provide 10 Accessory Drives

tion, form an assembly by themselves as in Fig. 6. This construction makes it possible to divide the engine into two units for assembly and for service work. One is the "power end," which is shown in Fig. 7, consisting of the main case, nose, crankshaft, connecting-rods, pistons, cylinders, and valve-gear, and the other is the "accessory end," including the mounting, supercharger and gearing and all accessories and their drives. Should occasion arise, the power end can be removed from an airplane and another substituted without disturbing the accessory end. This is possible because the engine is supported on the blower section. Care was taken to arrange the support as nearly on the center of gravity of the engine and as far from the crankshaft as possible. High crank-speeds have been provided for by the solid master-rod, large-diameter crankshaft, unique crankcase and method of engine support.

High power-output involves both uniform fuel-mixture distribution and complete filling of the cylinders. None

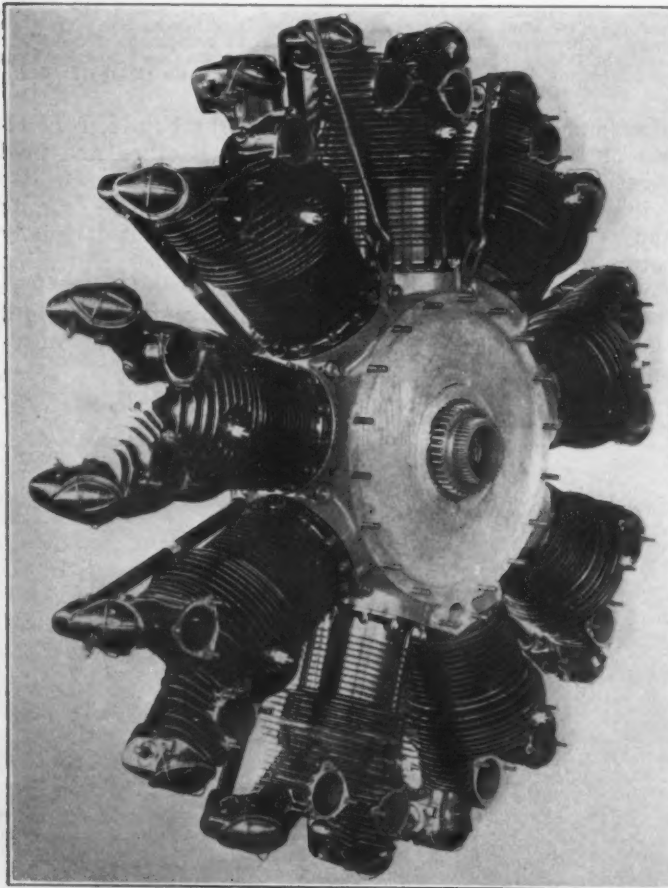


FIG. 7—REAR OF POWER END OF THE WASP

This Unit Assembly Complete Is Supported on the Blower Section of the Accessories Assembly by the Bolts Shown. The Dual Gear Supplies the Drive to the Three Large Spur-Gears of the Assembly Unit and to a Step-Up Gear That Drives the Supercharger Impeller

of the various manifold and carburetor arrangements previously used has provided entirely satisfactory induction. After considerable study, we concluded that distribution by a high-speed impeller was nearly ideal. This provides for uniform distribution, unusual acceleration and any degree of supercharging that the fuel used will permit. The intake system therefore consists of a double Stromberg carburetor that supplies gas to a General Electric impeller running at five times the crank speed, or 10,000 r.p.m. at normal speed. The impeller

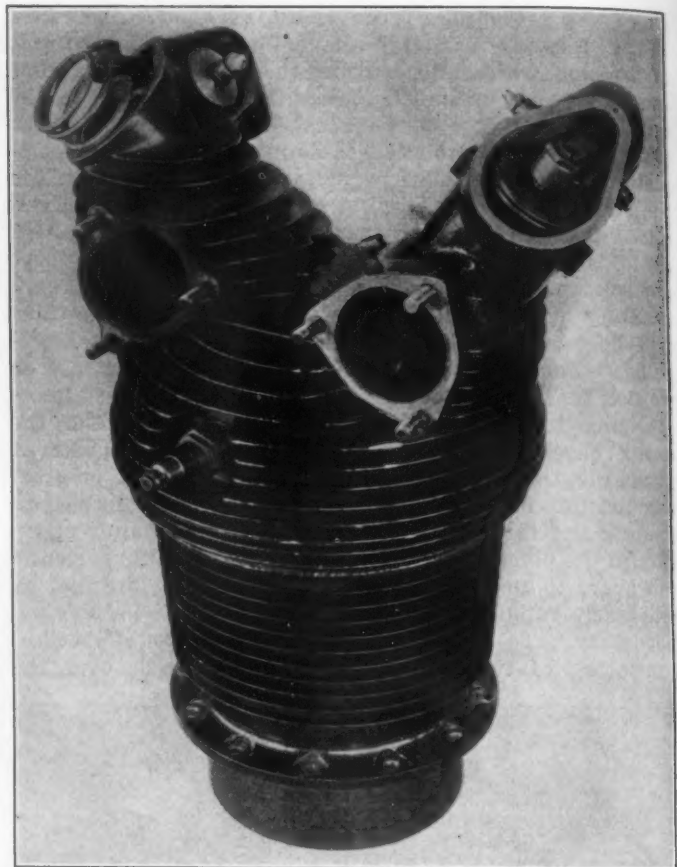


FIG. 8—CYLINDER WITH ENCLOSED VALVE-MECHANISM

Distribution of the Fuel Mixture Is by a High-Speed Impeller That Delivers the Gas to an Annulus through Diffuser Vanes, Whence It Is Led to the Cylinders by Tangential Tubes. Boxes for the Valve Rocker-Arms and Valve-Springs Are Cast Integrally with the Cylinder-Head and Protected by a Detachable Cover Held on by a Wire Bail. The Combustion-Chamber Is Hemispherical and the Piston-Head Concave, thus Providing Good Turbulence and Superior Heat-Radiation. Valve Ports Are of Large Diameter and the Valves Are Placed at Right Angles to the Plane of the Crankshaft and at a Large Included Angle, so That Excellent Cooling Conditions Are Afforded

delivers the gas to an annulus through diffuser vanes, whence it is led to the cylinders by tangential pipes.

ENCLOSED VALVE-GEAR QUICKLY ACCESSIBLE

Because of the bore-stroke ratio of 1 to 1, large valves and ports can be used. The valve-operating mechanism was the subject of much study. We wanted a gear that was robust yet simple and durable; moreover, it must be completely enclosed, properly lubricated and readily accessible. The cam drive consists of spur-gears that drive the cam drum through internal teeth cut in the



FIG. 9—NAVY CURTISS FIGHTING AIRPLANE WITH WASP ENGINE
Bayonet-Type Straight Tapered Muffling-Stacks Are Attached Directly to the Exhaust Ports of the Several Cylinders and Are Lighter and More Accessible than a Ring Exhaust-Collector. Note the Cowling of the Engine between the Cylinders and around the Propeller Hub

drum. The cams and their drive are enclosed in the nose section of the case and are lubricated under pressure. After considerable experience with compensating valve gears, we decided that enclosed compensated gears are rather intricate and not particularly durable, hence rocker boxes were formed as a part of the cylinder-head casting, as illustrated in Fig. 8. Each of these boxes is provided with a quickly detachable cover that is held on by a bail wire and completely encloses both the rocker-arm and the valve-springs. In conjunction with the telescopic push-rod enclosure-tube, the whole valve-gear is enclosed but is quickly accessible for inspection. The rocker-arms are mounted on small ball-bearings that obviate the need for daily lubrication, yet provision is made for readily removing the valve-springs without the necessity of dismantling the rocker-arm assembly. Timing-compensation for the elongation of the cylinders is provided in the cam and tappets.

CYLINDER DESIGN GIVES HIGH EFFICIENCY

The cylinder design was predicated on a desire to obtain maximum power. This required the best possible cooling and large ports. The cylinder disposition of the

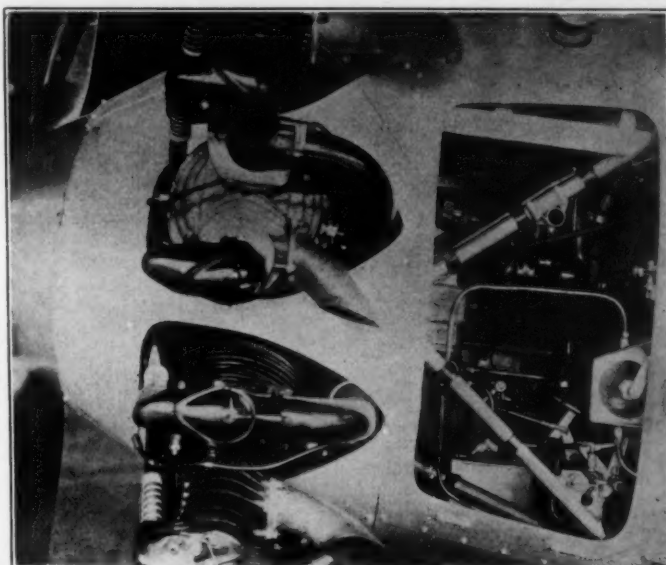


FIG. 11—ACCESSIBILITY OF ACCESSORIES THROUGH COWL OPENING
Side Openings in the Cowl of the Apache Provide Ready Access to All the Engine Accessories from Both Sides of the Fuselage

ports in an effort to reduce the over-all diameter is considerable, we decided that ideal conditions would provide such an increase in power as would more than compensate for the slightly greater diameter. Therefore we use a hemispherical combustion-chamber and a concave piston, which arrangement provides perfect combustion conditions, including good turbulence and the maximum radiating-surface. By placing the valves in a plane at right angles to the crankshaft and at a large included angle, excellent cooling conditions are provided not only over the head of the cylinder but around the valve-seats. The intake and exhaust ports are both open to the rear,



FIG. 10—WRIGHT APACHE AIRPLANE WITH WASP INSTALLED
Ease of Cowling Results in Unusually Fair and Symmetrical Fuselage Lines, and Complete Protection Is Afforded for All the Engine Accessories, Which Are Carried at the Rear of the Crankcase and Completely Enclosed in the Forward Bay of the Fuselage ahead of the Fire-Wall

radial type alone provided uniform and maximum cooling for each cylinder, which is of utmost importance for maximum power. This cylinder arrangement has another feature of great merit from a service standpoint; namely, the ease with which individual cylinders can be removed without disturbing the timing or the remainder of the engine. Although the urge to restrict both the shape of the combustion-chamber and the size of the

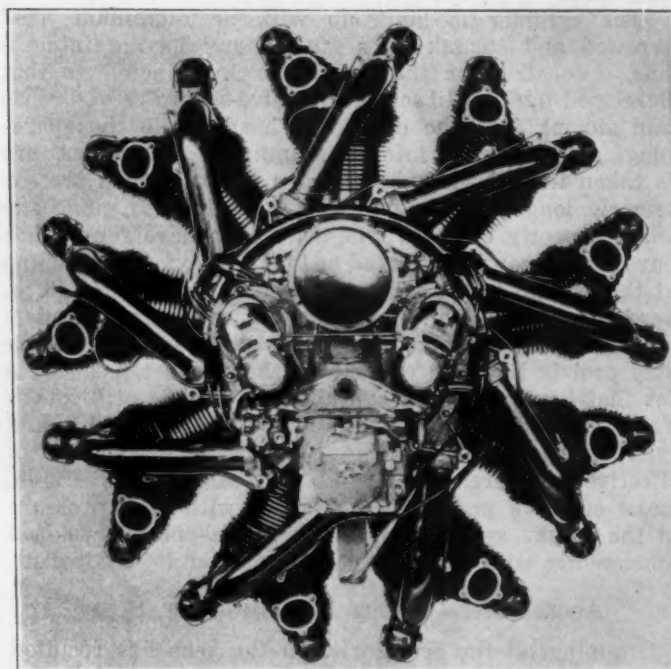


FIG. 12—ACCESSORY END OF THE WASP ENGINE

Above the Center and between the Two Magnetos Is the Starter. Directly below This Is the Double Carburetor. To the Right of the Carburetor Is the Oil Pump and to the Left Is the Fuel Pump. Directly ahead of the Carburetor Is a Large Oil-Strainer Chamber and an Oil-Pressure Regulator. The Ingenious Arrangement of the Accessories, Including a Supercharger Impeller, Synchronizers and Tachometer and Their Drives, Results in an Engine of Very Low Dry-Weight

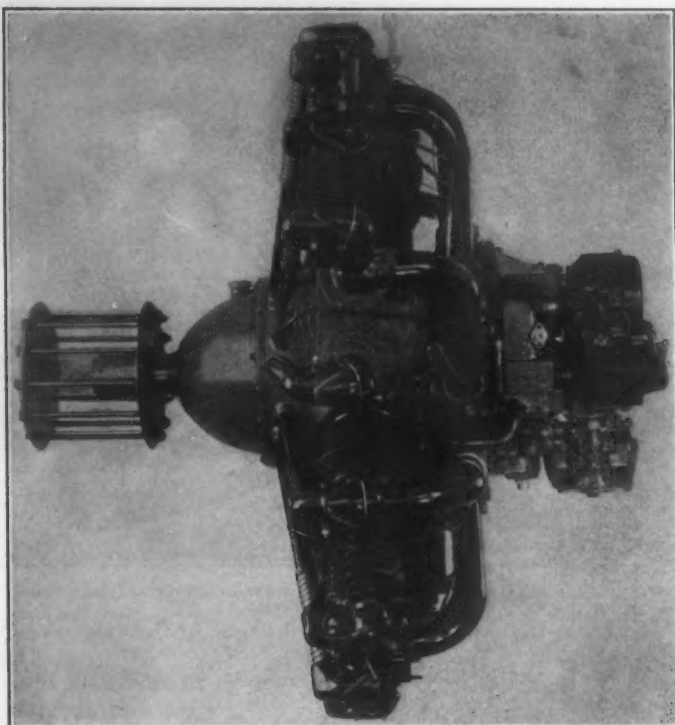


FIG. 13—PRATT & WHITNEY HORNET ENGINE

Work on This Big Brother of the Wasp Was Started Last Winter and the Engine Was Ready to Run in June, 1926. Design of the Two Engines Is Identical Except That the Hornet Has 25 Per Cent More Piston Displacement and Is Built Both with and without Propeller Reduction-Gearing

which further improves the air-flow around the heads. This arrangement provides for an exhaust collector just behind the cylinders or for straight muffling-stacks, as suggested by the Curtiss Wasp installations, as shown in Fig. 9.

The cylinder is built up with an aluminum head screwed and shrunk on a steel barrel having integral fins, a construction that is similar in principle to that developed by Dr. Gibson. The valve-seats are of bronze and shrunk into the aluminum head, while the spark-plugs screw directly into the aluminum. Particular care is taken to cool the exhaust-valve guides, which are extremely long for this purpose, as well as to guide the valve properly onto its true seat. We have found that our engines can be operated on straight aviation gasoline at their rated power with a fuel consumption of 0.48 lb. per hp-hr. This is an excellent measure of good cylinder-cooling. Further proof that these cylinders run remarkably cool is that the enamel on the exhaust ports of a set that have now been run about 300 hr. is still intact. This combination of the induction system, valve-gear and cylinder cooling has made possible very good mean effective pressure. On standard straight fuel, 130-lb. mean effective pressure is obtained with zero pressure in the intake system, while 140 lb. has been developed consistently with 30 per cent of benzol or its equivalent.

ACCESSORIES GROUPED IN REMOVABLE UNIT

Grouping all the accessories in the rear has resulted in an engine that is easy to cowl and that provides for unusually fair and symmetrical fuselage lines, as may be seen in Fig. 10, which is important for superior airplane performance. Equally as important as these aerodynamic features is the complete protection of all accessories. These are carried at the rear of the crankcase and behind the mounting, where they are completely en-

closed in the forward bay of the fuselage just ahead of the fire-wall. Ready access to all the accessories is provided through a single opening in the cowl on either side of the airplane, as in Fig. 11.

The accessory drives were a considerable problem, since we desired to use the minimum number of gears, preferably all of the spur type, to arrange for removing the engine from the airplane without dismounting anything else and still have as compact and light an assembly as possible. When it is considered that drives must be provided for two magnetos, a starter, two synchronizer-heads, a tachometer, generator, oil pump, and fuel pump, as well as for a step-up gear for the supercharger, a total of 10 drives, it will be realized that the solution was not easy. We finally used three lay-shafts approximately 120 deg. apart, all driven from the crankshaft by a single spur-gear as shown in Fig. 6. An Eclipse momentum starter engages with the uppermost shaft through a dog-clutch. Provision is made on the shaft for a generator-drive by using a pair of bevel-gears. Each of the lower shafts drives a Scintilla magneto at its outboard extremity. In addition, three bevel-gears provide a vertical drive, both upward and downward, from each lower lay-shaft. Upward, they drive directly the synchronizer heads and indirectly, by a small worm-gear, the tachometer. Downward, one drives the fuel pump and the other the oil pump. The crankshaft gear previously mentioned is a dual spur, one gear of which drives the supercharger impeller through a spur step-up.

By reference to Fig. 12 it will be seen that the starter is located above and between the two magnetos, while the carburetor attaches to an elbow that is a part of the magneto support. The oil pump is on the right side of the engine and the fuel pump occupies a similar posi-

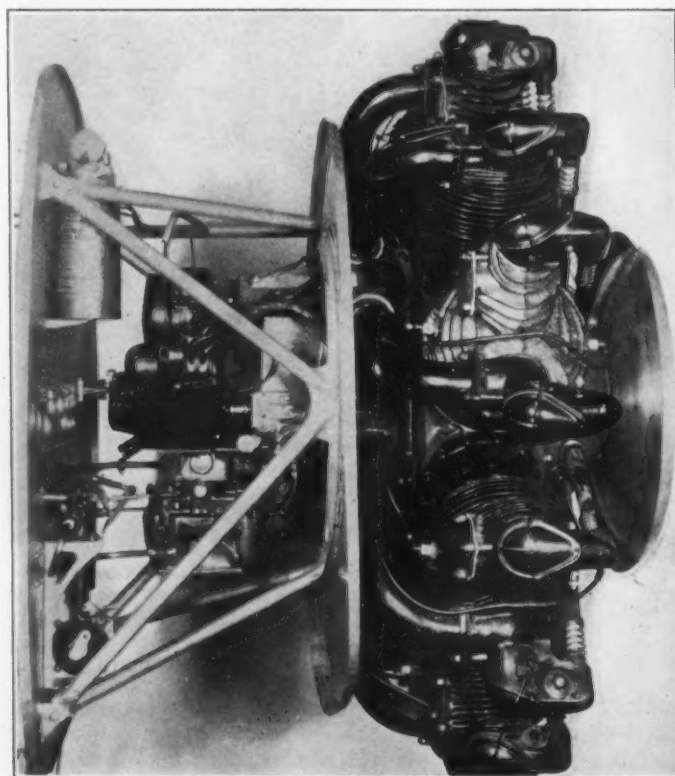


FIG. 14—MOUNTING OF WASP ENGINE IN VOGHT AIRPLANE

Lightness and Simplicity of the Strut Arrangement Are Evident. Accessibility of the Cylinders and Accessories with Cowl Removed Is Equally Obvious, as Is Also the Fact That the Whole Powerplant Mounting Is Dismountable by the Removal of Four Bolts in the Support after Disconnecting the Controls and Instruments

WASP AND HORNET AERONAUTIC ENGINES

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tion on the left side. A large oil-strainer chamber is provided directly ahead of the carbureter, together with a readily accessible oil-pressure regulator.

By minute attention to detail, the dry weight of the engine has been kept very low. Undoubtedly the radial type lends itself to the lightest design possible owing to its short crankshaft, compact crankcase and absence of any tinware for uniform cylinder-cooling. The usual instrument connections are provided, including one each for the oil-outlet temperature-gage, oil-pressure gage, fuel-pressure gage, and the like.

The design of the Wasp was started on Aug. 1, 1925, with a clean sheet of paper and no old tools or policies to hinder us. By concentration of effort we had the first engine turning over on Dec. 24, 1925, or less than 5 months later. In this time, the entire engine was designed; patterns, dies and tools made; and the engine fabricated. In a single year, we have carried the development of this type to a point where one engine has had about 300 hr. of running and three engines have been flight-tested in as many different airplanes.

The design of the Hornet, shown in Fig. 13, which is the big brother of the Wasp, was started last winter, and this engine was ready to run early in June. The Hornet and Wasp are identical except that the former has approximately 25 per cent more piston displacement and is being built both with and without propeller reduction-gearing.

BETTER AIRPLANE PERFORMANCE DEMONSTRATED

As the proof of the engine is, in the last analysis, in the airplane performance, to glance briefly at the results that have been attained in this direction seems worthwhile. Experimental installations of the Wasp have been made in two fighting airplanes designed originally for water-cooled engines, and these converted airplanes not only have developed high speeds equal to those with the original engines but have demonstrated materially improved rate of climb and lower landing-speeds. That these results are to be regarded as only first approximations should be emphasized. Substantial weight-savings

have been accomplished, but they affected only the powerplants and merely indicated what may be expected when a wholly new airplane-design extends them to the entire airplane-structure. Already a new Vought airplane designed especially for this engine incorporates a distinctly better and much lighter mounting, as shown in Fig. 14.

In aerodynamic characteristics also the recent installations are by no means to be considered as embodying the ultimate possibilities. The cowling of radial engines has received comparatively little attention in this Country, and to suppose that further study and experimentation will result in methods of cowling that will attain much lower air-resistance without sacrifice of proper cooling is only reasonable. Although few data on the air-resistance of air-cooled cylinders seem to be available, the experience gained in the recent installations, in which no attempt was made to reduce resistance other than to continue the fuselage lines as much as possible between the cylinders, shows that this resistance is much less than had been supposed and seems definitely less than that of a water-cooled engine with a radiator. When the installation of air-cooled engines has been as thoroughly worked-out as has that of water-cooled engines, the superiority of the newer type of powerplant should be even more evident.

At present, we are observing not only the first steps in the development of radial engines for fighting airplanes but also the first step in the development of fighting airplanes for radial engines. The radial engine, as a type, may be said to stand only upon the threshold of its development. Water-cooled types of engine represent a number of years of improvement and perfection. In my opinion as much improvement is possible in the radial type in the future. When we consider that the radial engine at present has demonstrated that it can out-perform its water-cooled competitor in an airplane, great progress seems to be assured for this type in the future.

[The discussion following the presentation of this paper is printed on p. 616.]

WORLD CURRENCY SYSTEMS

THE effect of the war on the currency systems of the world was tremendous. Until last year the United States and Sweden were the only countries where the gold standard functioned without governmental interference. For 7 years most of the trade of the world was conducted in terms of currencies that fluctuated rapidly and made future calculations extremely difficult. After years of chaos and dislocation, however, the European currency position began to improve quickly with the assumption of gold payments by

Great Britain in April, 1925. Following England's example, the Netherlands, Australia, New Zealand, and the Dutch East Indies have returned to the gold standard, while several other countries, notably Argentina and Japan, are ready to resume gold payments in the near future. Furthermore, Germany, Austria, Hungary, and Switzerland have stable currencies, while paper inflation in Norway and Denmark has been relatively slight and does not offer any problems of major importance.—*Guaranty Survey*.

THE STUDY OF STREET TRAFFIC

IN connection with the Erskine Bureau for Traffic Research, which has been established at Harvard through the generosity of the Studebaker Corporation of America, that company has endowed two fellowships, and they have been assigned to Granville G. Hulse, and Maxwell N. Halsey, each of whom is a research fellow in street traffic.

Last year Mr. Hulse was a special court investigator in

the examination of the street traffic in Chicago and is carrying on a nation-wide survey of the organization and functions of police courts in relation to their handling of traffic problems. Mr. Halsey is making a study of the relation between traffic problems and the movement for the decentralization of retail business in the great cities of the Country.—*Harvard Alumni Bulletin*.

Discussion of Papers at the Aeronautic Meeting

DISCUSSION that followed the presentation of the three papers at the Engine Session of the Aeronautic Meeting in Philadelphia last September relates to all three papers and was entirely verbal. Abstracts from the papers by E. T. Jones and Commander E. E. Wilson, which were printed in THE JOURNAL for September, 1926, are reprinted here for the convenience

of members who did not attend the meeting and to refresh the memory of those who heard the papers and discussion. The paper by George J. Mead on the Wasp and Hornet radial air-cooled engines is presented on p. 609 in this issue. The edited transcript of each speaker's remarks in the discussion was submitted to him for approval or correction before publication herein.

THE DEVELOPMENT OF THE WRIGHT WHIRLWIND TYPE J-5 AIRCRAFT-ENGINE

BY E. T. JONES¹

ABSTRACT

CONFINING his subject matter strictly to a discussion of the Wright Whirlwind engine and its bearing on the present status of the air-cooled aircraft-engine, the author says that the type of engine specified embodies in its development two distinct forms of cylinder construction, the first having been developed by Charles L. Lawrance and the second by S. D. Heron. The application of these cylinders to the engine under discussion is outlined and the subsequent development is traced.

The development of the J-5 type of engine was undertaken in an effort to place the air-cooled engine fully on a par with the water-cooled type as regards fuel consumption. The cylinder is characterized by a hemispherical combustion-chamber employing two valves with axes inclined at 70 deg. The valve-seats are of aluminum-bronze shrunk into the cast-aluminum head. The cylinder-barrel with integral cooling-fins and hold-down flange is screwed and shrunk into the aluminum-head casting. Among the advantages claimed for this cylinder over the Lawrance type of cylinder are superior head-cooling due to the larger fin-area provided by the hemispherical combustion-chamber and the relatively large space between the valve-ports; the superior barrel-cooling due to the integral steel-fins, which avoids the necessity of conducting the heat across a thermal gap between the aluminum barrel and the steel liner; the high fuel-economy presumably due to the excellent combustion-chamber shape and to the

efficiency of the valve cooling; greater strength and ability to withstand abuse due to the hemispherical shape of the combustion-chamber and the superior cooling; and remarkable freedom from detonation presumably due to the combustion-chamber shape, valve cooling and spark-plug position. The shape of the combustion-chamber is also said to offer the further advantage that relatively large valves can be employed without unduly crowding the valve-seats together at the center of the head.

Cooling efficiency and fuel consumption are considered and the results of endurance tests of the J-5 engine are stated. Briefly, the engine was subjected to a 50-hr. test under full throttle at 2000 r.p.m. and showed a fuel consumption of 0.508 lb. per hp-hr.; to a 50-hr. test under full throttle at 1800 r.p.m., in which the fuel consumption was 0.458 lb. per hp-hr.; and to a 50-hr. test while supercharged, developing 295 hp. at 2150 r.p.m. and showing a fuel consumption of 0.510 lb. per hp-hr. Domestic aviation-gasoline was used in the foregoing tests. The author believes that the results of these endurance tests place the air-cooled engine definitely on an equal footing with the best water-cooled engines and that the air-cooled engine will become the standard of comparison. His final conclusion is that the development of the air-cooled engine will advance with the utmost rapidity during the next 3 years, since there is still room for great improvement in all respects including specific weight, power output per cubic inch, cooling capacity, durability, and facility of production.

AIR-COOLED ENGINES IN NAVAL AIRCRAFT

BY COMMANDER E. E. WILSON², U. S. N.

ABSTRACT

THE purpose of the paper is to point out the basic policies which have resulted in the fostering of air-cooled-engine development by the Navy, and to indicate where the development has led. Two roles, played by naval aviation are designated "air service" and "air force." The former term refers to the func-

tions of naval aircraft which are contributory to the ships of the fleets, such as scouting and the control of gun-fire. The latter term refers to the functions which involve the use of aircraft as an integral and component part of the Navy's striking force, such as combat, bombing and torpedo launching.

Seven different types of aircraft are required by the Navy for its different purposes, these being airplanes for training, fighting, observation, scouting, torpedoing, bombing, and patrol use. Scouting, torpedoing, bombing and patrol functions have been combined into

¹ M.S.A.E.—Chief powerplant engineer, Wright Aeronautical Corporation, Paterson, N. J.

² Head of engine section, Bureau of Aeronautics, Navy Department, City of Washington.

one type in the past, but any airplane which combines multiple functions must suffer in its performance of the individual functions and it is desirable to provide a specific type for each required function.

Subsequent to specifying the engines now used in the airplanes for training, for fighting and for observation and saying that water-cooled engines in the 200-hp. field have been definitely supplanted by the air-cooled type, the author passes to a recitation of pertinent features connected with airplane tests conducted by the Bureau of Aeronautics with air-cooled engines installed in high-speed aircraft suitable for fighting. He states that the air-cooled engine has entered the pursuit field definitely to challenge the water-cooled engine and then discusses supercharging with Roots-blower-type superchargers, following this with description regarding recent application of the air-cooled engine to the bombing and the torpedoing-airplane classes.

The statement that the tendency to increase power is not sound is analyzed, as well as the preference in the Navy's development for radial rather than in-line air-cooled engines. The Navy is rapidly obtaining a line of three air-cooled engines that will meet most of its requirements. The large air-cooled engines are now equipped with 2 to 1 reduction-gears and can be installed with geared or with direct drive in twin-engined patrol-airplanes. Thus, the Navy then has the entire range of its aircraft air-cooled.

Since the approval of the basic policy to make naval aviation an integral and component part of the fleet that must go to sea with the fleet, the outlining of the types of aircraft required and their general characteristics, all the Navy's engines for aircraft have been developed for a specific purpose and it now has water-cooled engines of from 200 to 800 hp. and air-cooled engines of from 200 to 500 hp., the service ratings of which are shown in a chart. The requirements are low weight per horsepower, high economy in fuel, maximum dependability, maximum durability, maximum ease in maintenance, minimum cost, and easy adaptability to quantity production. With these requirements in mind, the author estimates the progress that has been made in naval-aircraft development, considering fuel economy, cooling efficiency, powerplant economy, dependability, durability, maintenance, cost, and production.

THE DISCUSSION

A MEMBER:—I was interested particularly in Mr. Jones's statement of the power required by the supercharger on the Whirlwind engine, which is the only 200-hp. engine that is available at present for commercial use.

Although air-cooled engines no doubt are coming to the fore and practically every company building engines is interested in them, the water-cooled engines are by no means obsolete; see the water-cooled engines that are being used in the Air Service, where every kind of engine has a place. Both types of engine are being used in Europe. Trouble from water-cooling systems has been experienced mostly because the men handling the engine have not been trained.

Mr. Jones stated that it was better to run the Whirlwind at a lower speed to increase the mean effective pressure, thereby increasing the difficulties of cooling. Unless the engine were run beyond the peak of the power curve it would develop more brake-horsepower with increased speed and would have to be cooled more. The fuel contains a certain number of British thermal units and if more work is obtained from the engine it is

harder to cool. I would like to ask Mr. Jones if the power is actually lower at the higher speed.

E. T. JONES:—The power is not lower at the higher revolutions per minute but our experience indicates that the cooling difficulties increase more rapidly with an increase in mean effective pressure than they do with an increase in speed. In other words, for a given cylinder design operating on a fixed fuel consumption, we have less trouble in increasing the power by raising the number of revolutions per minute than we do by raising the brake mean effective pressure.

COMMERCIAL BUILDERS NEED COST REDUCTION

R. W. A. BREWER:—The highly interesting papers presented have not dealt with the subject of cost, except in the final remarks of Commander Wilson regarding the advantage in cost of the radial-type air-cooled engine. Mr. Jones said almost incidentally that the commercial demand for the Whirlwind engine is increasing to such an extent that 19 commercial operators are now using that type of engine, which fact will make a reduction in cost possible.

We who are primarily interested in commercial aviation know that we and our customers cannot spend \$5,000 and upward for an engine. The great problem now before us is the cost and to what extent the designer and manufacturer can compromise the ideals of engine design and construction to keep the cost of the final product within the means of our possible market. We know, for example, that a large market exists in certain fields to supplant the OX-5 type of engine. Certain operators who have had airplanes built for this type of engine have used the Whirlwind engine costing \$5,000 with great success, and to hear that the engine probably will be put into commercial production at a figure much more within the means of the airplane builder and the man who we hope will be a purchaser of an airplane is interesting.

Ours is a different problem from the one faced by the designers who delivered the papers. We have to design and build down to a cost. When we start to make anything we must think of our market and at the very top of our schedule must put our prices, based to a great extent upon the cost of certain necessary devices, such as engine starter, magneto and carbureter. These accessories have been produced principally for the Government, to whom the matter of dollars is not a prime consideration. In the first place, the accessory manufacturers must be convinced that we need an absolutely dependable line of moderate-priced accessories which will be accepted by our customers. So far, I have found the accessory manufacturers willing to try to meet our needs. I mention this because, in the type of engine we have in mind, the cost of accessories that we cannot make ourselves but must buy in the market is too large in proportion to the total purchase price of the engine.

We arrive at once, therefore, at a maximum price that we can pay for the engine. Our next task is to make a survey of engines available at a cost that has as its basis such a figure as we have decided upon. If that is to be say between \$1,000 and \$2,000, our accessories will not represent an abnormally high proportion of the total cost. We should like to use beautiful engines such as the Wasp and Whirlwind, but to turn out such an engine at a price the customers, in our limited possible market will pay, is impossible. So we must make the parts, such for example as the cylinders, at a fraction of the cost involved in the production of cylinders of the Wasp type and so on right down the line. In arriving at sizes and shapes we must always have cost in mind and

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whether we can, by another disposition of those dimensions, reduce the cost.

I believe that never has this reasoning been followed in radial-engine design because it has not been necessary, but it is one of the vital points. If we must have a certain number of cubic inches of cylinder capacity around a crankcase, we must crowd as much of it as possible close to the crankshaft and at the same time work out the engineering problems in such a way that the pieces comprising the complete structure can be made simply, easily and cheaply and of low-cost materials, not at aviation prices, and can be quickly and easily replaced in the open market.

If one buys an aviation valve he must pay probably \$9.50 each for a fitting of unusually high-grade steel, because our design has not provided for sufficient thermal conductivity and eliminates the use of certain lower-priced materials. This brings up the question: How far can we go with expensive materials? With the addition of a little weight a less expensive material can be used and this will enable us to cheapen our product to a great extent. By analyzing the production of a commercial air-cooled radial engine the cost can be cut to a fraction of that of the Wasp type by sacrificing something. The statement has been made that to sacrifice five or six Liberty engines to buy an engine that will last, pays. To sacrifice design and material even though we must add weight will pay us, as by so doing we shall obtain customers.

SALES VOLUME FOLLOWS GOOD PERFORMANCE

W. B. STOUT*:—I think Charles M. Manly, who built the first radial engine, should say a few words.

C. M. MANLY*:—I think no one is more keenly interested than I am in the development of aeronautic engines in general and especially radial engines. I am delighted to see the great progress that is being made with the radial engine by Mr. Lawrance in this Country and by others both in this and in foreign countries.

Referring to the remarks made by Mr. Brewer, I think a note of caution might well be sounded. We do not need to worry much about how we are to work-out the economically commercial product until we get the engines themselves to performing as we want them to perform. I used to worry considerably back in 1898 to 1900 about how we would ever be able to build an engine cheaply enough and sufficiently reliable to make the automobile economically commercial. Today the cheapest-built engine, that has about \$7 worth of labor in it, is a much better product than those we put several thousand dollars' worth of experimental labor into at that time. This is due to the cooperative work of many persons who have taken different views of the many problems and thus brought all to a final result that has changed all of our past perspective as to where the troubles would lie. Problems that seem difficult to some are not difficult for others. Constant improvement and perfection of detail finally will bring the desired result, not only with the engine as a whole but with all these problems of accessories. The various units that Mr. Brewer spoke of as being very expensive are a certain drag now, but men who have not spent a great sum of money in experimental work will come along and, not having incurred a

heavy overhead expense in development work, will probably put out of business the men who have done the developing by producing the units much cheaper. Probably the outcome will not be different in this field from what it has been in others.

Those who are doing this development work should profit by the history of other developments, such as the automobile, and try to produce as near the readily marketable price as possible, at the same time pushing the quality of the product, so far as performance is concerned, to the point of actually getting reliable results, because to obtain thoroughly reliable performance is necessary before you can build up a large commercial transportation business; then some way will be found of producing the engines cheaply.

H. CAMINEZ*:—Our company approaches the problem not by trying to make our detailed parts any cheaper but by developing an engine of low cost through simplification of design. To that end we are using the fewest possible cylinders that will give satisfactory and smooth running, keeping the number of detailed parts down to the minimum and maintaining the quality. We believe this to be a much sounder policy because to try to work with inferior material or cheap manufacturing methods in aircraft engines is not right.

ENGINE-SPEED OF THE RADIAL INFERIOR

A MEMBER:—Two problems of the radial engine have been argued. One is that it cannot be turned at as high speed as the water-cooled engine, and the other is how to take care of the exhaust. Cumbersome ring-type manifolds never are mentioned in the weight per horsepower. Unfortunately, they weigh considerable and do not last long. That problem has been solved fairly well by the Curtiss-Kemble taper-type muffler shown on the Wasp engine in the Hawk airplane, although it does not conduct away the exhaust so that it will not be objectionable on commercial passenger-liners.

The problem of high speed may be solved with the Wasp engine; the builders are determining that now by flight service. With the water-cooled engine, when the airplane is turned into a vertical dive from an altitude of 10,000 ft., the engine turns up to more than 3000 r.p.m. With the heavy reciprocating weight of the radial type of engine one wonders whether the engine will stand up at such a speed. We have had instances in which the water-cooled engine has turned up so fast that the tachometer pointer has gone round against the pin and the pilot did not know what the engine-speed was. High engine-speed will be the next problem to be solved with the radial type of engine, and the designers are trying to solve it.

GEORGE J. MEAD*:—Why is high crank-speed so essential?

A MEMBER:—High crank-speed is not essential but unfortunately it occurs when the airplane is turned down with the engine throttle open.

MR. MEAD:—Airplane performance rather than engine crank-speed is what we are all interested in. If a certain type of engine will give better performance than another in the same airplane at lower crank-speed, so much the better.

A MEMBER:—With a given piston-displacement the question arises, How fast can the engine be turned up? We know that high engine-speed is one way to obtain maximum airplane performance.

MR. MEAD:—This has been talked about for years. The water-cooled engine has been forced to run fast in an endeavor to make up for the weight of its cooling

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* Jun. S.A.E.—Vice-president in charge of engineering, Fairchild-Caminez Engine Corporation, Farmingdale, N. Y.

* M.S.A.E.—Vice-president, Pratt & Whitney Aircraft Co., Hartford, Conn.

system. If the radial engine turns 3000 r.p.m., most likely the water-cooled engine must be able to turn 4000 or 5000 r.p.m. to give the same performance.

A MEMBER:—The idea I am trying to emphasize is that the engine-speed goes up because a dive is made with the throttle open.

MR. MEAD:—The engine-speed will be in relation to the level-flight propeller-speed. In our case the engine turns at 1900 r.p.m. in level flight; in a dive the highest speed recorded is about 2400 r.p.m. in a straight-down dive for a good many thousand feet.

A MEMBER:—If this engine will stand an engine-speed of 2400 r.p.m. it is the proper development.

MR. MEAD:—This is a general argument that has been carried on for years and this is the first time we have had any proof on the side of the radial engine. We want to make some more test flights and turn-up the engine to more nearly what the D-12 engine does, but this is the first time we have had these engines in the air and their performance seems to be at least comparable with that of the corresponding water-cooled engine turning much faster. We feel that the diving speed depends more upon the weight of the airplane than on the engine-speed. If we had an extra-heavy engine we could out-dive anybody!

HAVE ONLY BEGUN DEVELOPING SPEED POSSIBILITIES

C. L. LAWRENCE⁸:—With the old type of connecting-rod held together by four bolts many difficulties undoubtedly develop at high engine-speed, such as scuffing of the parts and breakage of the bolts, but with a one-piece connecting-rod, in which no localization of stresses occurs due to the forces having to pass through the bolts, the construction is much stronger than the standard connecting-rod of a water-cooled engine. I doubt very much whether any more trouble due to connecting-rod failure will occur in running a radial engine up to high speeds than occurs with water-cooled engines. Experience has shown lately that we can run them up to somewhat high speeds, and I think we have only begun to develop the possibilities.

The loading on the bearing of a radial engine does not remain in the same place but travels around the circumference of the bearing, so that during the non-explosion strokes and two revolutions of the crankshaft the load has traveled twice around the bearing. If proper cooling is furnished for that bearing, no reason exists for its failure, whereas in a V-type engine the load is sustained in much the same place all the time. I believe the crux of the whole matter is the single-piece connecting-rod as opposed to the bolted connecting-rod.

DETERMINATION OF WORKING SPEEDS DURING THE WAR

W. H. BARLING⁹:—A successful practice used in England during the war to determine engine-speed was as follows: An aircraft engine supplied by a builder was run for a short time on the test block at its designed speed. We did not have time to make elaborate experiments. It was then put into an airplane coupled to a propeller allowing the engine to run at its designed speed. A climb to 10,000 ft. was made and if satisfactory on this test the propeller was carved to allow the engine to run at 200 r.p.m. more, and another climb made. This was repeated until finally we burst each

make of engine. This method lightened the engines per horsepower and also determined the working revolutions per minute of the engines. In the case of the Rolls-Royce engine we began with about 1200 r.p.m., then increased to 1400, 1600, 1800, 1950, and 2100, until it burst at about 2300 r.p.m. After that we worked these engines to 1950 r.p.m. The plan was to work all engines at from 200 to 300 r.p.m. less than the speed at which they would actually burst, unless the power-curve peak was passed.

Bursting tests were conducted by starting an airplane from the ground and climbing as fast as possible. The engine was cold at the start. Bursting of all the

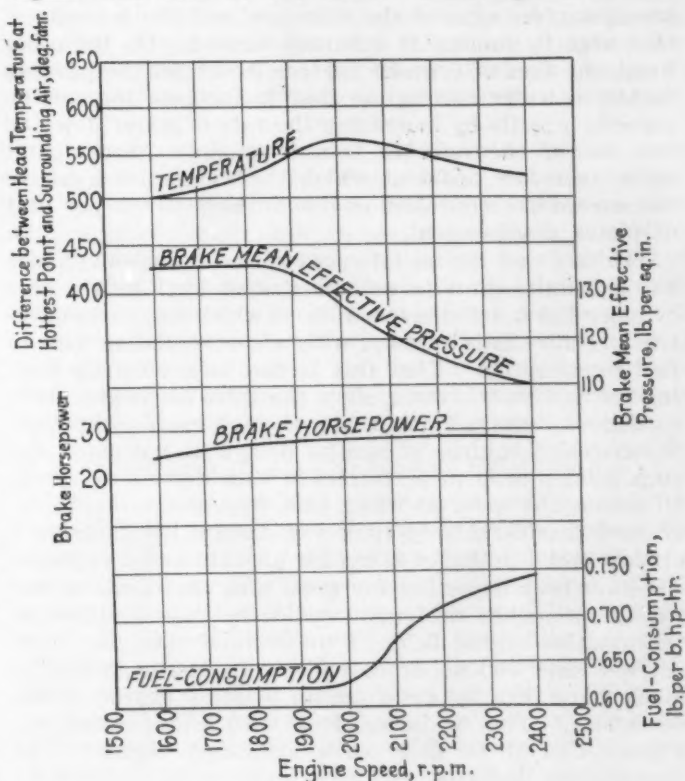


FIG. 1.—PERFORMANCE CURVES OF AN AIR-COOLED CYLINDER
These Curves Illustrate the Fact That the Useful Speed of Such a Cylinder Has a Definite Limit, Which Is the Speed above Which the Mean Effective Pressure Drops Rapidly with a Corresponding Rise in Fuel Consumption. While the Speed at Which This Drop Occurs Can Be Increased Considerably, Some Such Critical Speed Probably Exists for Any Air-Cooled Cylinder

engines occurred between 5000 and 7000-ft. altitude. One could smell the engine becoming hotter and hotter as he went up. Above 7000 ft. the atmospheric temperature was lower and if the engine did not burst between 5000 and 7000 ft., it probably would be all right up to 10,000 ft. Then the pilot would come down and more material would be cut off.

A great number of the engines were designed for speeds far below those at which they were used satisfactorily.

SURVIVAL BY HIGH SPEED ONLY

C. F. TAYLOR¹⁰:—I have been identified with the development of air-cooled engines for some time but cannot see the water-cooled engine put aside without saying something in its favor. Engine-speed, it seems to me, is the one factor that may give the water-cooled engine a chance to survive in aeronautics. Obviously an engine of given size, if run twice as fast and at the same mean effective pressure, will give twice the power. Possibly the limiting mechanical features may not differ greatly

⁸ M.S.A.E.—President and general manager, Wright Aeronautical Corporation, Paterson, N. J.

⁹ M.S.A.E.—Chief engineer, Cox-Klemin Aircraft Co., Baldwin, N. Y.

¹⁰ M.S.A.E.—Associate professor of research in aeronautical and automotive powerplants, Massachusetts Institute of Technology, Cambridge, Mass.

between the two types, although when nine cylinders are working on one crankpin the limiting speed seemingly is bound to be lower than when two cylinders are working on one crankpin. However, granting Mr. Lawrance's contention that this problem can be solved and that the air-cooled and water-cooled engines will be equal in this respect, the question of cooling remains, Can the air-cooled engine be cooled indefinitely as the speed increases?

The cooling required on a given cylinder is a function of horsepower per unit of heat-dissipation area, and the direct air-cooled engine has a definitely limited dissipation area. One can utilize no more than the entire external surface area of the cylinders, and the increase of that area by finning is definitely limited. On the other hand, the area of cylinder surface is not yet the limiting factor in water cooling, so that to increase the cooling capacity greatly by increasing the rate of water flow and the size of the radiator is still possible. Some point must, therefore, exist at which the water-cooled engine can exceed the air-cooled engine in horsepower per unit of piston displacement.

The fact that the useful speed of an air-cooled cylinder has a definite limit is well illustrated by Fig. 1. This cylinder has a definite speed above which the mean effective pressure falls rapidly, with a corresponding rise in fuel consumption. That this is due to inadequate cooling seems almost certain, since the valve areas and other conditions were all favorable to high-speed operation. Water-cooled engines of similar design do not show any such sudden drop in performance with increasing speed. Of course the speed at which this drop occurs can be increased considerably by improved design, but some such critical speed probably exists for any air-cooled cylinder.

I have been expecting for some time that some of our racing-automobile designers would try their abilities in the aviation-engine field. I understand that they now get well over 100 hp. from a 91-cu. in. engine, which is much more than we get from an aviation engine of the same size. This is being done with water-cooled engines. Can it be done with air-cooled engines? It seems to me doubtful.

These very high speeds at present presuppose a lower degree of reliability than with moderate speed. Whether our aircraft engines can be developed to turn very much faster than they now do and still retain a sufficient degree of reliability is doubtful. However, if the water-cooled engine is to survive, I think that it will have to be by a drastic increase in speed with a corresponding increase in power per unit of cylinder displacement.

TEMPERATURE DOES NOT AFFECT FUEL CONSUMPTION

WESLEY L. SMITH²¹:—Have any of the air-cooled-engine engineers measured the differences in fuel consumption that attend changes in outside temperature? What happens when the temperature is —40 deg. fahr. and when the temperature is 120 deg. fahr.? We have to meet those conditions and, while we never have operated air-cooled engines, we would like to know if any change in fuel or oil consumption occurs.

MR. JONES:—Such tests as we have been able to make indicate that, if to enrich the fuel mixture to prevent detonation is not necessary, the fuel consumption is practically independent of the operating temperatures of the engine. That conclusion is not based upon elaborate research. We have checked the fuel consumption within

a few per cent from one time of the year to another. If an engine operates close to the detonation point and is run in hot weather, more fuel probably must be used, not to get the engine to run but to run it without detonation.

A MEMBER:—If wing radiators instead of a tunnel radiator are used on the airplane the water-cooled engine will have a decided advantage over any air-cooled engine. The wing radiator has an adaptation in racing and also in commercial aviation. The point has been made that not enough care has been taken to improve the design of the airplane. Most of the advance in speed and performance has been due to increase of power. An opportunity exists for the designer to take advantage of the wing radiator for commercial purposes and increase the airplane efficiency by getting more air-speed with the same power.

PROPELLER AND ENGINE PERFORMANCE LINKED-UP

MR. STOUT:—Another aspect of this engine question is involved with that of engine-speed. Before discussing that I wish to tell some experiences with airplane models. I started a number of groups of high-school boys in different cities on modeling airplanes. Those boys can make a model that weighs 4 oz., complete, and will fly for 10 min. They can make a model that weighs 1/6 oz., set it for a certain ceiling, and it will go up and stay at that height for 1½ min. and then come down.

Those boys have attained to an accuracy that I do not think our big-airplane designers have reached. I say this advisedly because three of our best commercial airplanes, so-called, designed around the OX-5 engine, have been designed by former model-airplane boys from Chicago who never saw the inside of a university and would not know a slide rule if they saw one, yet they have been out-performing the experts so far as their aerodynamic engineering is concerned.

In an airplane model the propeller diameter is from one-fourth to one-third the span of the wings. That is of great importance. When one is making a model that weighs 1 oz. or less and is endeavoring to win a prize for endurance with it, he must try to get the maximum out of a total power furnished by a pair of 1/16-in. rubber bands. If a small propeller turning at high speed or a larger one turning at slower speed were better, the fact would be found out in one flight across this room. Propeller weight increases rapidly with diameter, hence the size of the propeller is even more important in these models than with engine-driven airplanes in which gears can be added to take advantage of the high engine-speed. One boy finally came out with a propeller with one blade and a counterbalance on the other side. All laughed at him but he sent his model up and it stayed up for more than 10 min. and made a world's record.

Propeller performance is so definitely linked-up with engine performance that they can no more be separated in an airplane than in a motorboat or steamship. I have in mind an airplane built for a certain division of the Army and equipped with a Liberty-12 engine. At the end of its test those who tried it out said it climbed as high as a water-tower in 20 min. with its full load; it was absolutely unusable. Then some one with queer ideas suggested that a geared Liberty engine be installed. As an experiment they put in one of the old geared Liberty engines and fitted it with a 14-ft. propeller. With the same engine-speed and same horsepower that airplane had a very creditable performance, a higher flying-speed and carried a larger useful load, and was

²¹ Pilot, Air Mail Service, New Brunswick, N. J.

very usable, simply because of the greater swept-area of the propeller.

Therefore, with regard to the slower revolutions of the radial engines, we should remember that the propellers will turn at slower and more efficient speed because they will sweep a larger area. More than that, the diameter of the engine with the larger propeller is of less retarding effect because the central part of the slow-speed propeller is not efficient and might as well be cowled-out. With the larger propeller and the slower speeds, we solve the problem of the greater diameter of the radial engine and I think we will find that the gain from the propeller on direct drive will more than make up for the greater engine-speed of the water-cooled engine with the addition of gears. The whole question of gearing-down lies in the future, while with the radial engine it is not necessary.

Another fact regarding water-cooling should be mentioned. We have been driving our airplanes on the Ford air routes with Liberty-12 engines for about 1½ years. The ships make two round trips per day from Detroit to Cleveland and one round trip to Chicago. We have, we believe, as good mechanics as any in the world and we believe they know how to mount a radiator and a Liberty engine; yet 90 per cent of all of our forced landings due to mechanical trouble have been caused by the plumbing and water troubles. Therefore, from actual operating experience with water-cooling we are much in favor of the simpler air-cooled system and, while we may get greater power with water-cooling, I am of the opinion that air-cooling is an inevitable development for aircraft.

COST REDUCTION A BASIC REASON FOR AIR-COOLED ENGINE DEVELOPMENT

COMMANDER E. E. WILSON:—The very fundamentals that Mr. Brewer outlined in connection with cost reduction on these engines were the basic reasons for our undertaking this new development with the Wright Aeronautical Corporation. We reasoned that, inasmuch as 200-hp. engines are now definitely used in the training field, we could afford to abandon some of those requirements that are needed for high-performance aircraft and bring through a special training-engine.

The important thing to remember, however, in the matter of cost is that we cannot sacrifice dependability, durability or economical maintenance for low first cost in this field in which hazards measure the whole problem so largely. The important element, as I endeavored to point out in my paper, is the volume of production. We say today that with present production the Wasp engine will probably cost us \$9,000. We can buy one of the best automobiles in the world for \$9,000, but suppose we were building only 200 of these automobiles in a year, what would the cost be? The fact of importance regarding this low-powered engine is that as soon as the Army Air Service has used up all of its Hispano and Liberty engines and standardizes on the air-cooled type, and when commercial requirements have advanced to the point where the demand for commercial purposes will be good, if the Army, Navy and commercial users can concentrate on one type of engine in the 200-hp. field we shall get the costs down.

In our basic policy in the Navy we have deliberately discontinued the use of Hispano and Liberty engines and gone into the new development with the idea that the present engines constitute a reserve. We shall need them in the event of a war emergency to tide over the interval during which the Country is getting into production on the new engines. When commercial demands are large

the cost of this little model J engine will be reduced materially. Against that time we hope to bring through, as our contribution in the development of the training engine, an engine of 200 hp. that will be of sufficiently low cost to warrant the Navy, the Army and commercial builders using the same style of engine.

I was greatly interested to see and hear Mr. Manly because about 2 years ago, when I was preparing a paper for the American Society of Mechanical Engineers, I had occasion to talk with Commander Leighton and Mr. Mead, who said that one day they were going through the Smithsonian Institute and discovered a little engine there that seemed to embody all the fundamental characteristics of the modern radial design that they were advocating. They found that Mr. Manly had designed this engine 20 years ago and that it was basically in accord with our conceptions, which had been arrived at after 20 years of grief.

I was also interested to see Mr. Caminez, because he is making a definite bid for fame with a low-cost engine; but in any of these developments we should remember that a good engine is of no use unless there is a place for it. In bringing through any design, bearing in mind where the particular engine is to be used is important. If the Caminez engine is suitable for training for the Army and Navy and for commercial activities, then it has a tremendous market and we hope that the development which is going on will be continued because it is extremely interesting to everyone concerned.

NEED DATA ON GEARED-ENGINE PERFORMANCE

The discussion on high crank-speed goes on continuously. The rise of the air-cooled engine forced the water-cooled engine to high crank-speeds so that it could compete, but, as Mr. Stout pointed out, we must remember that crank speed is a function also of the airplane. J. G. Vincent, I believe, said in a paper that we could count on about 10 r.p.m. per m.p.h., perhaps, for the best economy. That being the case, in a 125-m.p.h. airplane, 1200 r.p.m. is probably the best engine-speed. Yet for low weight per horsepower we are turning these engines at 2000 r.p.m. The solution is to gear the propeller down. That idea was brought out in our PN-9 and PN-10 airplanes in which, with the reduction gearing installed in Packard engines that are turning 2500 r.p.m. in level flight, we are able to get off the ground with tremendously heavy loads because of the high propeller-thrust for take-off and to get high propeller efficiency for long-range flights. The secret of the success of the PN-9 was 2-to-1 reduction gearing.

When we undertake these different designs, however, we find that we are more or less uncertain. Does the weight of the propeller and reduction gearing counterbalance the improvement in thrust? No definite figures are available to work from except that we have certain examples of improved performance with the use of reduction gearing. For that reason, when we started to build the Hornet, we incorporated a 2-to-1 reduction gear but realized that the gear was useless unless we could turn the engine up to high speed. Again, the question arises whether the ratio should be 2 to 1 or 5 to 3 or some other.

In connection with the National Advisory Committee for Aeronautics we have initiated a series of performance tests at Langley Field, using different types of gears, different ratios, different degrees of supercharging, and different crank-speeds, with the object of obtaining some data that can be used. So many variables are linked-up in the problem that to arrive at a definite con-

clusion is hard. However, this question of crank speed, as Mr. Stout says, is definitely linked-up with speed of the airplane.

What Mr. Barling said about high revolutions per minute was of interest. We have held back in the matter of high engine-speed very largely because of mental hazards. We thought we were doing rather well when we turned the water-cooled engines at 2100 r.p.m. Then we increased the speed to 2500, and now it is 2800 r.p.m. One of our little Packard engines developed 500 hp. at 2100 r.p.m., passed a 50-hr. test, with wide-open throttle, with only two stops, developing 600 hp. at 2500 r.p.m., and our racing engine recently showed 700 hp. at 2800 r.p.m.

We felt the same way about the radial engines. Several years ago we thought that the model J was limited to 1800 r.p.m., but now we are turning it up at 2100 and 2200 r.p.m. and diving the engine at 2500 r.p.m.

COOLING ALWAYS LIMITED BY CYLINDER AREA

I cannot coincide with Mr. Taylor's reasoning about the cooling area being limited in the air-cooled engine and not in the water-cooled engine. I think that the cooling area is not a question of radiator surface but of cylinder capacity and surface. How big the radiator is makes no difference if the water cannot be brought into contact with the surface to be cooled.

Mr. Taylor spoke also of the high horsepower per cubic inch of piston displacement in automobile racing-engines. We should remember that those performances involved high crank-speeds and exceedingly small cylinder-diameters in comparison with the diameters we are using. We all are familiar with the effect of increased cylinder-diameter and low speed on detonation, and detonation is the controlling factor.

Mr. Jones answered perfectly Mr. Smith's question about change in fuel consumption with differences in atmospheric temperature. Between Richard Byrd at the North Pole and some of our own seaplane pilots over the Red Sea, Navy fliers are experiencing the extremes of

low and high temperature. So far as we can find out, the atmospheric temperature makes no difference whatever on fuel consumption so long as detonation is avoided.

With reference to wing radiators, we have found them unsuitable for military purposes because of the difficulty of maintenance, the problem of plumbing and their vulnerability as a military hazard.

Mr. Stout's figures on failures of the water system are even larger than those we have thought were the average. We find that about 60 per cent of our failures are due to the plumbing and that they are about equally divided among the water, gasoline and oil systems.

I want to make clear in connection with the cylinder design of the Wasp and Hornet engines that the Pratt & Whitney design is based largely upon the work of Dr. Gibson, with improvements and refinements by Mr. Mead, and is separate and distinct from the work that was done by S. D. Heron at McCook Field, Dayton. We have two distinct types of modern cylinder-construction, the one exemplified by Mr. Heron's work at McCook Field, which type is now used by the Wright Company, and the one presented by Mr. Mead, which is used in the Wasp. Each type is such a great improvement over any we have had before that we are convinced that these engines are doing better than any water-cooled engine has done, as we are able to supercharge these air-cooled aviation engines at sea-level to a high degree, something we have not been able to do with the water-cooled engines.

I want to make myself understood clearly in this discussion that we do not think for a moment that the water-cooled engine is doomed. It will always have a place; for instance, we find with the Loening Amphibian that we are obliged to continue to use the water-cooled type. However, that the air-cooled engine is bound to predominate, except for these special applications, seems probable because the direct method of doing anything is always better than the indirect, and in the air-cooled engine the direct method of cooling is employed as against the indirect cooling of the water-cooled engine.

DEEP OIL-WELL DRILLING PRACTICE

THE Shell Co. of California has pioneered in perfecting a device recently put on the market for ascertaining definitely the points at which water is entering completed or producing oil wells. This is done through careful measurements of the electrical conductivity of the fluids of the well. The well is first conditioned by washing with fresh water and the fluid is then bailed from the top sufficiently to entice the water from the formation into the hole. Next the device is operated, the points where the fluid conducts an electric current most easily being points of high salt-content and thus indicating the entry of water.

To survey an oil well is now possible. An instrument that measures both the inclination and direction of the hole is run on the drill pipe or tubing, measurements being taken a stand apart, or approximately every 80 ft. Many rotary holes, thus surveyed, have been found to be as much as 150 ft. out of vertical.

How deep can the present-day rotary drill? The ordinary

draw works, with the driller at the brake and throttle, is gradually approaching its limit. The weight to be given the pipe and the speed at which it should be rotated on a 10,000-ft. hole will be too delicate matters for the ordinary driller to judge without further practical aid. Perhaps the solution will be some automatic feeding device such as the Hild differential, directed by an engineer who can calculate what stresses and strains should be required of his drill pipe.

The day of the 7500-ft. hole is here. The rotary drilling machine as at present constituted is fully capable. When oil is found in commercial quantities at this depth, an entire field of 7500-ft. wells will appear. Whether it is possible to drill so deep a hole is no longer a question. A 7500-ft. hole can be drilled at reasonable cost by any experienced operator who will buy the best in equipment, secure the best in men and then use care, and still more care.—R. H. Garrison in a paper presented at a meeting of the American Petroleum Institute.



The High-Performance Small Car Here and Abroad

By THOMAS J. LITTLE JR.¹

PENNSYLVANIA SECTION PAPER

ABSTRACT

STATING his belief that we are on the threshold of the most revolutionary development that the industry has ever witnessed and remarking the stages through which the industry has passed, the author mentions the apparent settling down of the industry to the refinement of its product and says that comfort and performance now dominate the American mind in its demand for better automotive transportation. He believes that America will not copy the foreign car, although the good features of the many foreign designs are recognized; but he predicts that the influence of racing-engine development will be felt and that the present ideas of engine building will be entirely changed on account of the wonderful performance of racing cars, the result being a small high-speed high-power passenger-car engine operating at a speed of at least 4000 r.p.m. Eventually the author sees the completed evolution of a small car that will be equipped just as luxuriously as the finest car on the American market, one that will be fitted with a special custom body but will be in no sense cheap.

Regarding the present types of car, the author prophesies first, the elimination of the very cheap hard-riding car of obsolete design; second, the discarding of the medium-priced car in about the same class; and third, that the new engineering school will create the fine small car. Although he recognizes that the American and the European problems are very different, he says that Europeans are coming gradually to the American idea and that the European public eventually will buy millions of new cars of a type that will provide comfort, luxury and maximum performance. He is convinced that the industry can learn much from the designers of racing cars and that supercharging and the use of high-compression fuels will be included in future improvements. He sees an era of production of many fine small and medium-size cars and the formation of many new companies for that accomplishment.

FORMERLY, as an engineering executive and now as a consultant, I have studied the European and the American car-trends carefully and believe that we are on the threshold of the most revolutionary development that the industry has ever witnessed. We have experienced all the stages through which other great industries have struggled, from the inception and experimental stage to that of small production as the plaything of the rich. Then we progressed to enormous production of a pretty rough product to meet a great transportation demand that we had created. Now we are finally settling down to refine our product and put in some real engineering that will be worthy of our profession. Comfort and performance now dominate the American mind in its demand for better automotive transportation.

Our present product is sadly lacking in many details. We have built millions of vehicles and still have not yet filled the enormous demand and, of course, under such circumstances, we did not improve our product as rapidly

as we would have done had we been forced by competition to do so. The excessive demand was fine for dividends but not for improvement.

WILL AMERICA COPY THE FOREIGN CAR?

Recently, the question arose: Will America copy the foreign car? My answer is: "No." But we recognize the good features of many foreign designs. The difficulty with many of them is that the cars, which are of necessity very small, have inadequate powerplants. This situation is forced by the high tax that most of the European countries have seen fit to impose on cylinder-bore and fuel. In spite of this policy, however, the industry in Europe has grown with leaps and bounds.

I know that my view that small high-speed high-power passenger-car engines will be evolved from the wonderful little racing engines that have fascinated us during the last year, will not be shared by a large group of engineers and executives of the industry. I do not claim that these racing engines actually will be used in passenger-cars, but I predict that our ideas of engine building will be entirely changed on account of the wonderful performance of the racing cars.

About 15 years ago we were using in our passenger-cars, ponderous slow-speed engines that we would now call marine-type engines. At that time there was great furor in the industry when an engineer first proposed to cut down the weight and increase the engine-speed. It was predicted that such engines would fly to pieces and, of course, some such engines that were not properly designed, virtually did so. But this development was a milestone in the automotive industry. The engine of the future, while not as high-speed as the racing engine, unquestionably will operate at a speed of at least 4000 r.p.m.; and, later, this speed will be increased.

A small car will be evolved that will be equipped just as luxuriously as the finest large car on the American market. This type of car will be fitted with a special custom body and will be in no sense cheap. Engineering effort will develop the same riding-qualities and greater acceleration than the large de luxe car now possesses. Following this development of the small luxurious car will be the development of cars of the medium-price class in somewhat cheaper reproduction. For both of these classes of car, the public will willingly pay for the better performance and luxurious equipment.

TRENDS OF THE VARIOUS PRESENT TYPES OF CAR

I am fully convinced that, while the large luxurious car will always be built in America, the large cheap car will disappear from our market. The trend in the large de luxe car will be toward larger powerplants, of 8 or 12 cylinders. The power-weight ratio of our larger cars is too low. Their powerplants must be increased in power or their bodies made lighter.

The low-priced four-cylinder car will gradually pass away. It will be superseded and out-performed by the small smooth-running six, propelled by a little high-speed high-compression high-economy engine.

¹ M.S.A.E.—Engineering production consultant, Detroit; vice-president in charge of engineering, Copeland Products, Inc., Detroit.

The need is for more engineering work in body building. Bodies are becoming larger and heavier. The all-metal construction is not contributing to light weight.

The aluminum industry was unquestionably shortsighted when it maintained high prices for body metal and virtually forced every American manufacturer out of its market. We hear rumors, of course, that this situation will be changed, though we have not seen much evidence of it.

The fabric body has received considerable attention abroad, but it has not received much encouragement in this Country. That, like the sleeve-valve engine, this development will remain dormant for a number of years and suddenly break out into something very interesting, is entirely possible.

Returning to the small high-performance car, I predict a tremendous demand for this type in the American market. Families are now buying two and three cars, where as but a few years ago one car was considered almost a luxury. The order of this buying will be: the first car, probably in the large luxurious class; the second car, in the medium-price class luxuriously equipped with its high-speed efficient engine; and the third car, an ordinary dependable type of small transportation medium.

Great necessity exists today for intensive research on the riding-quality of our vehicles. I do not mean by this that we should be satisfied to fit some type of shock-absorber on a poorly designed hard-riding chassis to sell it, as is so often done. Each component part should be studied carefully and specially designed instruments developed for this purpose. How many engineers actually have used the seismograph to study riding-quality?

I thus predict the gradual elimination of a great many of our present-day cars. First, we will eliminate the very cheap hard-riding car of obsolete design. Then we will eliminate what we term the medium-price car, in about the same class. I shall emphasize this later, in detail.

THE FINE SMALL CAR

"A lot of car for the money" has ceased to be a successful sales argument. The new engineering school will create the fine small car. The fleet, low-hung masterpiece with soft purring engine will have the road virtually to itself immediately after the green light has flashed. The public will soon discard the lumbering cars and cease buying the cheap vibrating ones. Then the revolution in engineering will be complete.

The public can be depended upon for this, as it is extremely discriminating. Witness the transition from the harsh rasping phonograph to the rich resonant instrument of today. The phonograph industry had slumped badly but was completely revived by the revolutionary improvements in its product. We need never worry about the saturation point in our industry so long as we can improve our product progressively. The public

will discard the old for the new, willingly, or retain the old as a second or third car. Our people are prosperous and can well afford to do this.

THE EUROPEAN TREND

The American and the European problems are very different. In Europe, they have always been forced to skimp their powerplant for tax reasons and to adopt many gear-changes. Nevertheless, at this time they are ingeniously increasing their powerplants and advertising that they are gradually reducing the number of gear-changes. In other words, they are coming to the American idea. In America the public desires comfort, luxury and maximum performance and will buy millions of new cars of this type.

I believe that the trend in Europe will be to depart from the present diminutive car, compromising midway between the present European and American designs. Incidentally, this coming car will closely approach the new type of American car. In connection with my statement that engine-speeds will be 4000 r.p.m. and over, I call attention to the fact that the engines of several of our larger cars have been running close to this speed for some time, at their top speeds. Better workmanship and design unquestionably will be necessary in building the high-speed engines I predict.

I am convinced that we can learn much from our racing-car designers. One of the best attended and most spirited sessions ever held by the Society of Automotive Engineers was the one at French Lick Springs immediately following the last Indianapolis 500-mile race, when Harry Miller and Fred S. Duesenberg discussed their theories and designs with refreshing frankness.

CAR MATERIALS, SUPERCHARGING AND FUEL

I realize that better physical properties will be required in certain car parts, but that need not worry us as better steels are continually being produced. We have not yet taken full advantage of this. The supercharger is being studied and experimented with in every laboratory in the industry. I believe that superchargers will be used eventually on nearly all cars but not in their present form.

High-compression fuels are now becoming common. They will, of course, modify our designs. In every center throughout the industry I find the principal activities centered about the high-performance small car. Notwithstanding the centralizing trend to the larger companies, I predict an era of production of many fine small and medium-size cars, and the formation of many new companies. At a time like this, when the public is receptive to great improvement and has plenty of money, the organizer and the banker seize the opportunity for new company formation. Many such companies will survive if their product is engineered carefully.



Action, Application and Construction of Universal-Joints

By C. W. SPICER¹

PENNSYLVANIA SECTION PAPER

Illustrated with DRAWINGS AND PHOTOGRAPHS

ABSTRACT

USE of the universal-joint for transmitting power mechanically through an angle has been traced back as far as the thirteenth century when its use was described in a manuscript by Wilars de Honecort, an architect. This mechanism, which is essential in a motor-car, possesses the peculiarity that as the two shafts which it unites are rotated when at an angle to each other, it imparts to the driven shaft a non-uniform rotational velocity, and this becomes very erratic as the angle between the shafts approaches 90 deg.

This action has been analyzed by many writers by different methods; a clear and concise analysis was presented before the Society in 1908 by H. Vanderbeek, and some interesting curves showing the relative speeds of the shafts and how, by using a pair of universal-joints and an intermediate shaft, the erratic action of one can be made to compensate that of the other, were presented by Earle Buckingham in the *American Machinist* some years ago and are reproduced in the following paper. When the driving and driven shafts stand at right angles to each other a universal-joint connecting them becomes inoperative, and in practice the universal-joint is not useful in many installations at angles much beyond 45 deg.

To secure uniformity of velocity of the driving and driven shafts by the use of a pair of joints it is necessary that these shafts form equal angles with the intermediate shaft and that the axes of the joint yokes on the ends of the intermediate shaft lie in the same plane. With such an arrangement the universal-joint is so highly efficient at small angles that loss of power in transmission can be detected only by delicate and accurate instruments. The author shows the theoretically correct arrangement of a double-jointed propeller-shaft in a car in which a torque-arm is used; with Hotchkiss drive practical parallelism of the transmission-case shaft and rear-axle pinion-shaft is maintained.

Much inventive effort has been expended upon the designing of satisfactory universal joints, and a few examples have been selected from among hundreds of designs for illustration and description as typical of various principles employed, such as flexibility of metal and fabric, rolling steel balls, coiled springs, and accordion-type casings for retaining lubricant. Although most of these devices were not fully successful, many of the basic ideas embodied in them are in use in various types of universal-joints that are now offered in the market and that have been in use for years in automotive vehicles. The more prominent of present makes of universal-joint are illustrated and described, two types of which have not undergone any radical change in principle of action since they were introduced in 1904.

Universal-joints may be divided into three general classes: grease lubricated, oil lubricated, and non-lubricated. An ideal sought by some engineers is a joint that will perform its function satisfactorily with

no lubrication or other attention and have a life equal to that of the vehicle in which it is installed.

Claim is made for one type of joint now in the market that it "offers a method of obtaining a steady regular motion from the engine to the driving-wheels" and that where two joints are now used to compensate each other a single joint of this make "will take the place of the two joints of standard type." The uniform driving relation that distinguishes this joint is obtained by the use of a series of steel balls held in races milled in opposed faces of the interlocking jaws of the yokes. As angularity of the joint varies, the balls traverse only half the angular distance the jaws move and hence the balls always lie in a plane that bisects the angle between the shafts.

The essential working elements of the usual joint are two yokes disposed at right angles to each other and united by a four-arm cross. There are many modifications of this arrangement. Rolling steel balls held between the faces of the yoke ends or arms and the faces of the cross-arms add a supplemental principle, while live-rubber balls give a cushion effect that is highly desirable in some applications, such as in gasoline-electric drive. Flexible-disc joints are in a class by themselves and have been greatly improved by special construction of the fabric-and-rubber discs and the method of holding them to the spiders on the shaft ends so that the continuous flexure of the fabric will not disrupt it. Joints of several types as now made by various companies are illustrated and described.

MOST English text-books refer to the universal-joint as a Hooke's coupling. On the Continent it is referred to as a Cardan joint. So far as I have been able to learn, however, the first reference to the use of the universal-joint is found in a manuscript by Wilars de Honecort, a thirteenth-century architect. This was written about 300 years before Cardan's period, 1501 to 1576, and about 400 years before Robert Hooke was granted a patent on a universal-joint in 1664.

The universal-joint is a peculiar mechanism and is an essential part of a motor-car. As the angle between the driving and driven shafts which it joins increases beyond a very few degrees, the action of this joint becomes more and more individualistic until, as the angle approaches 90 deg., it becomes very erratic. At an angle of a little less than 90 deg. the driven shaft almost stands still while the driving-shaft rotates nearly 90 deg., then suddenly jumps ahead of the driver to nearly 180 deg. from the starting-point and there waits, with only a very small movement, for the driver to catch up. At full 90-deg. angle a universal-joint of the usual type will not work at all. Although it seldom is necessary to use universal-joints at great angles in motor-cars, their action at wide angles is an interesting curiosity and its study serves the useful purpose of indicating its nature at smaller angles.

Analysis of the variation of the speed relation between the driving and driven shafts has been attacked by numerous authors who have derived similar results by a

¹ M.S.A.E.—Vice-president and chief engineer, Spicer Mfg. Corporation, South Plainfield, N. J.

variety of mathematical procedure. No analysis that I have found, however, seems to me more clear and concise than the one presented before the Society in the autumn of 1908 by H. Vanderbeek on The Limitations of the Universal-Joint². In an article on the same subject which appeared several years ago in the *American Machinist*³, Earle Buckingham gave some interesting curves showing the relative speeds of the driving and driven shafts and also the actual angular variation in the relation of the driven shaft to the driving-shaft during a half revolution of a universal-joint at 10 different angles between the driving and the driven shafts. These curves, as reproduced in Fig. 1, give a clear picture of what actually occurs in the relations between two shafts from 0 to 89 deg. and 59 min. Mr. Buckingham has produced his last curve at 1 min. less than 90 deg. because at 90 deg. the curve would go to infinity and the joint would not be operative. As a matter of fact, the universal-joint would not be useful in many installations at angles much beyond 45 deg. Concerning the correction of this variation in the operation of a universal-joint, Mr. Vanderbeek wrote:

It is customary, where smooth running between driver and driven parts is desired, to use them in pairs; the effect of this arrangement is to correct

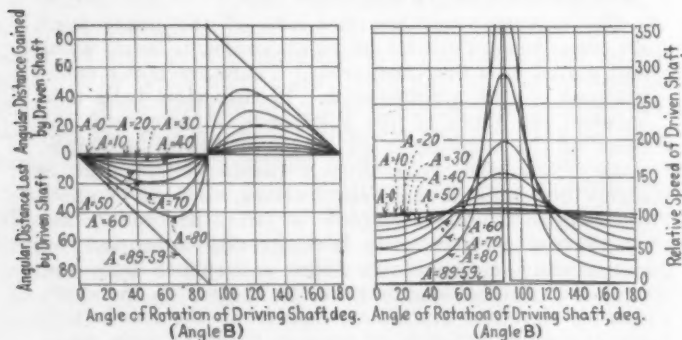


FIG. 1—RELATIVE SPEEDS OF DRIVING AND DRIVEN SHAFTS COUPLED BY A UNIVERSAL-JOINT, AND ANGULAR RELATION OF THE TWO AT VARIOUS ANGLES

These Curves Show the Changes in Relation of Rotating Speed of the Two Shafts at Various Angles from 0 to 89 Deg. 59 Min. With the Shafts at an Angle of 90 Deg. the Curves Would Go to Infinity and the Joint Would Be Inoperative

the variation of one joint by the complementary variation of the other. The graphical illustration of the effect of using joints in pairs may be shown by superimposing on the curve shown in Fig. 2 that of another joint in phase with the first but of opposite sign, as in Fig. 3. The conditions, however, which must be met in order to give this result are: That the fork axes of the intermediate shaft *B* must lie in the same plane and that the angle between both extreme shafts and the intermediate shaft shall be the same; this may be either as shown in Fig. 4 or Fig. 5 so long as the angle π equals the angle ψ . Evidently, the intermediate shaft *B* will have a varying angular velocity, but as this member is of small diameter and of light weight its non-uniform motion will cause no trouble in ordinary cases. It must be borne in mind, however, that we deal here only with that condition in which the axes of the driving and driven shafts *A* and *C* lie in some common plane.

HIGH EFFICIENCY AT SMALL ANGLES

It will be obvious that the efficiency of the universal-joint at wide angles is unavoidably comparatively low. This probably is the reason for the prevalent idea that the universal-joint is an inefficient mechanism. Careful

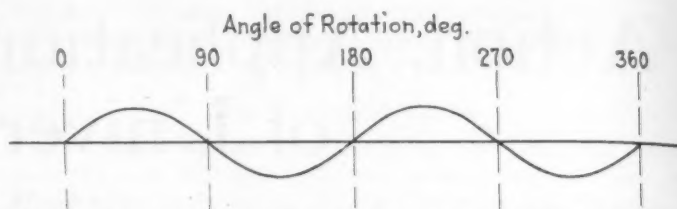


FIG. 2—ANGULAR VARIATION IN ONE JOINT DURING ONE REVOLUTION

tests show, however, that at angles of operation commonly encountered in motor-car service the efficiency is so high that the losses can be measured only with delicate and accurate instruments. The efficiency of the propeller-shaft that consists of two universal-joints and a connecting-shaft, as determined some years ago at the mechanical laboratory of the University of Kansas, has been plotted into the curves shown in Fig. 6 for angles up to 13 deg., with the assumption that both joints are working at the same angle. The upper and heavier curve shows the efficiency at normal full load when the two yokes at the ends of the connecting-shaft lie in the same plane. The lower and lighter curve shows how the efficiency drops when the propeller-shaft is assembled incorrectly with the two yokes at the ends of the connecting-shaft in the extreme condition of 90 deg. apart.

The two joints may be maintained at practically equal angles by proper design. Fig. 7 shows the theoretically proper hook-up when a torque-arm is used. The torque-arm should be pivoted at some point in a line which is at right angles to the center line of the propeller-shaft and situated equally distant between the centers of the two universal-joints. The pivot point may be anywhere in this line. The rear-axle pinion-shaft should be inclined upward as shown so that the angle π will equal the angle ψ . In the Hotchkiss drive, in which the pinion-shaft maintains a practically constant relation with the horizontal center line, it is usually desirable to place the pinion-shaft horizontal, or parallel with the transmission-shaft, as in Fig. 8, which relation usually will maintain angle π substantially equal to angle ψ .

If the yokes at the two ends of the connecting-shaft are assembled at right angles to each other instead of in the same plane, not only will loss of efficiency occur, as indicated by the curves in Fig. 6, but when the angles are more than about 5 deg. it may be possible, in an otherwise smooth-running car, to detect an actual surging action in the car when operating at very low speed due to the action of the joints. The same effect may occur when only one joint is used if the angle exceeds 6 or 7 deg.

Another difficulty from the same source came to my attention some time ago in a 5-ton short-wheelbase dump-truck that required an unusually short propeller-shaft and an operating angle in excess of 10 deg. in the joints. Joint failures were occurring on this type of truck under conditions in which the joints were expected to give reasonably good service. A fleet of the trucks was being operated on an excavation job and the work was being

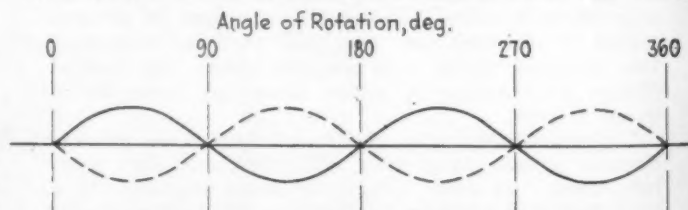


FIG. 3—SUPERIMPOSED CURVES SHOWING NEUTRALIZING EFFECT OF USING A SECOND JOINT IN PHASE WITH THE FIRST BUT OF OPPOSITE SIGN

² See TRANSACTIONS, September, 1908, p. 23.

³ See *American Machinist*, vol. 33, p. 108.

paid for on a per-load basis, hence the drivers wished to handle the greatest possible number of loads per day, and therefore returned from the dump to the excavation at the highest possible speed. The rear-axle gear-ratio was about 11 to 1 and the rear wheels were of rather heavy cast construction and fitted with wide solid tires, which combination had a considerable flywheel action at high speed. Careful calculation showed that at the angle at which the universal-joints were required to operate when there was no load on the truck, in connection with the high speed, the inertia of the rear-axle parts produced almost unbelievably great stresses in the universal-joints, which were so connected that one joint was doing most of the work and the bearing pressures

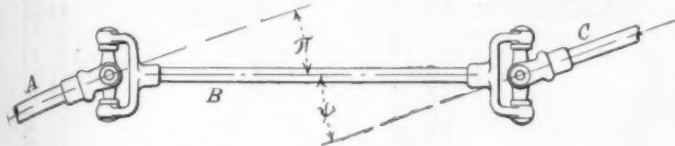


FIG. 4—ONE OF TWO ARRANGEMENTS OF A PAIR OF JOINTS TO CORRECT ANGULAR VARIATION AND ANGULAR VELOCITY
Axes of the Forks of the Intermediate Shaft *B* Must Lie in the Same Plane and the Angles π and ψ Between the Extreme Shafts *A* and *C* and Shaft *B* Must Be the Same

ran to values much above those encountered on the same job under normal conditions of load and speed.

DESIGN LIMITATIONS ATTRACT INVENTIVE GENIUS

The conditions of application of universal-joints are almost invariably such as to make minimum size and weight desirable, both because the allowable space usually is limited and, in these days, because small dimensions and light weight usually mean low cost, although this is not necessarily true in all cases. It is important for a number of reasons that the propeller-shaft should not be the weakest member in the power-transmission line of the motor-car, therefore it is necessary, notwithstanding limited space and desirable low cost, to so design this unit that its life will compare favorably with that of other important units of the car and that sudden failure

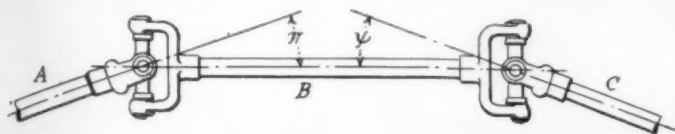


FIG. 5—ALTERNATE ARRANGEMENT OF COMPLEMENTARY JOINTS AND THEIR SHAFTS

cannot possibly result either from natural wear or lack of strength in emergencies. The limitations, together with the idiosyncracies mentioned, have made the universal-joint field an attractive one for inventors.

Designs collected from various sources show how one inventor has sought by the use of U-shaped sections to obtain the necessary flexibility for comparatively straight-line drive and at the same time gain strength by increasing the number of fastenings between metal and fabric parts. Another has sought to eliminate what he thought were the unknown values of fabric construction for, as he thought, known values for steel, obtaining at the same time an inexpensive construction by the use of a steel-cable ring; while still another has attempted to eliminate friction by the use of steel balls. A form worthy of special mention is a design in which a ball rolls back and forth in a short race to take the place of each pivot bearing, as this is typical of a somewhat large class of designs, one of which, to be illustrated later, in principle eliminates entirely the variation in angular relations that occurs in the customary types of universal-

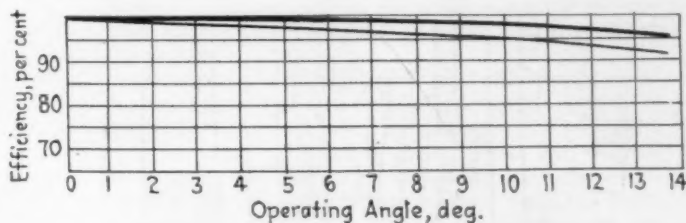


FIG. 6—CURVES OF UNIVERSAL-JOINT EFFICIENCY
The Upper Heavy Curve Indicates the Efficiency, at Normal Full Load, of a Propeller-Shaft Consisting of Two Universal-Joints and a Connecting-Shaft for Angles up to 13 Deg., with Both Joints Working at the Same Angle and with the Yokes in the Same Plane. The Lower Light Curve Shows the Efficiency When the Yokes Are Incorrectly Assembled with Their Axes at 90 Deg. to Each Other

joint. Instead of maintaining a fixed position with relation to each yoke, the pivot point moves back and forth with the ball in its race, one ball moving so as to shorten one arm of its yoke while the other ball moves to increase the length of its arm by an equal amount. This occurs in both yokes, and it can be demonstrated

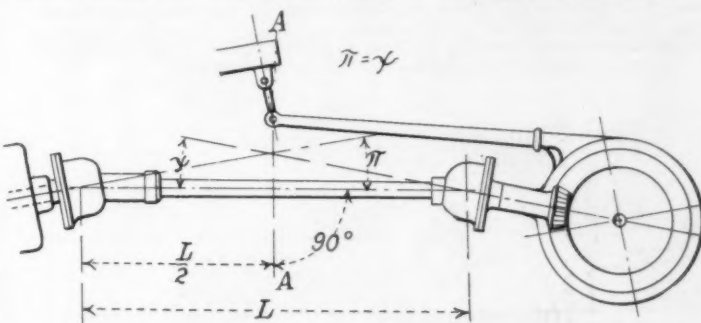


FIG. 7—PROPER APPLICATION OF JOINTED SHAFT WHEN A TORQUE-ARM IS USED

The Rear-Axle Pinion-Shaft Should Be Inclined upward so that Angle π Will Be Equal To Angle ψ . The Torque-Arm Should Be Pivoted at Some Point in a Line, *A, A*, Which Is at Right Angles to the Center Line of the Propeller-Shaft and Equally Distant between the Centers of the Joints. The Pivot Point May Be Anywhere in This Line

mathematically that the result is uniform angular relations between the driving and driven members of the single universal-joint.

Many designers have sought to take advantage of the flexibility of steel and some fairly successful designs have been produced for dynamometer use where available space permits of ample dimensions. In the limited space allowed in motor-car service, however, the sections apparently must be so heavy to give the required strength that they are stiff and very short lived because of the excessive flexure. A joint that has universal motion but is not a universal-joint in the usual sense is the coil-spring type, of which the Karge coupling is an example. This appears to be antedated by the Leaman patent issued in 1886, shown above the Karge coupling in Fig. 9, and several similar couplings dating back to 1871 or earlier.

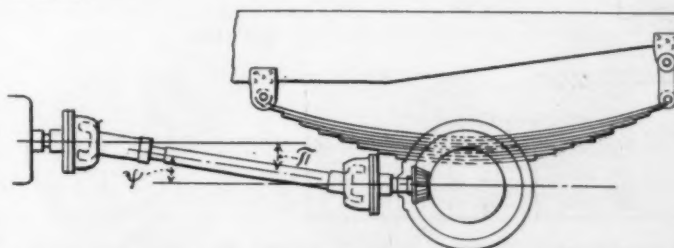


FIG. 8—APPLICATION OF PROPELLER-SHAFT AND UNIVERSAL-JOINTS WITH HOTCHKISS DRIVE

Equal Angles of the Transmission-Shaft and Pinion-Shaft with the Propeller-Shaft Are Maintained, Since the Pinion-Shaft, Which Is Preferably Placed Parallel with the Transmission-Shaft, Maintains a Practically Constant Relation with the Horizontal Center Line of the Drive

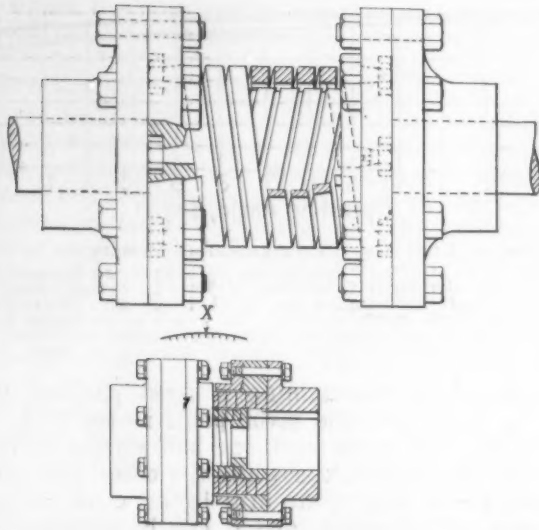


FIG. 9—COIL-SPRING COUPLINGS PATENTED BY LEAMAN AND KARGE
The Close Similarity of Construction of the Leaman Coupling, Shown above and Patented in 1886, with the Karge Coupling, Shown below and Patented in 1921, is Apparent

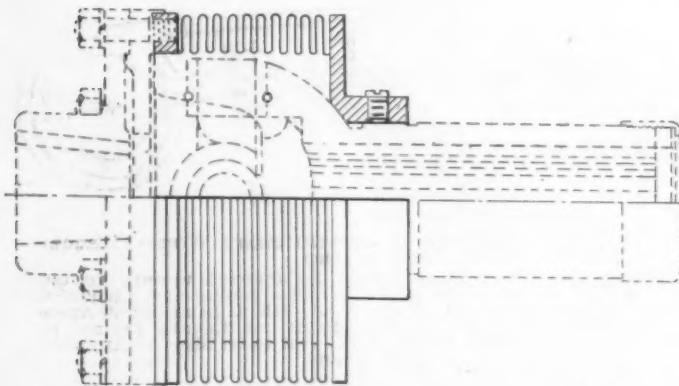


FIG. 10—JOINT WITH ACCORDION-TYPE CASING FOR RETAINING LUBRICANT

Flexure of the Casing Localizes at the Places where the Casing is Fastened to the Rigid Members and Causes It To Break Away after a Few Thousand Revolutions of the Shaft

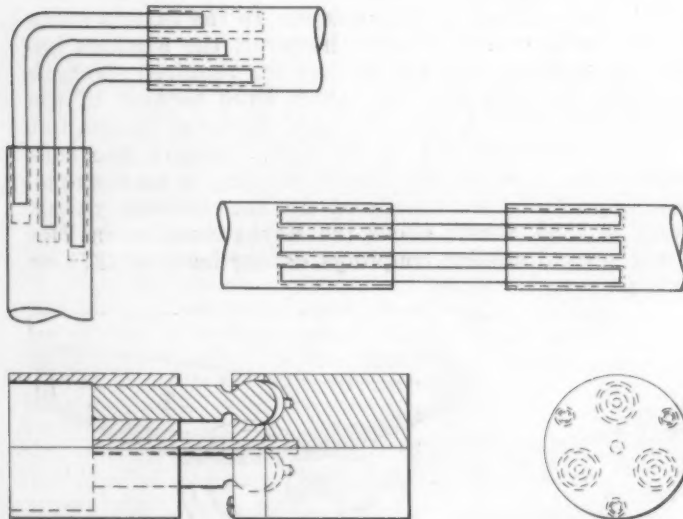


FIG. 11—UNUSUAL TYPES OF JOINT USED ONLY FOR CONSTANT-ANGLE WORK

The Gerome Joint, Shown above, Accommodates Itself to the Angle by the Ball-and-Socket Arrangement of the Pins, Whereas the Coupling Shown below Relies upon the Sliding of the Bent Rods in Their End-Bearings and Is Useful only for a Constant Predetermined Angle

One of the interesting means of the many that were tried to enable the universal-joint to retain its lubricant at high speeds was that proposed by G. E. Murphy and others of using an accordion-type casing, as shown in Fig. 10, such as is used for the various types of Sylphon regulator that are in common use. Unfortunately, when the joint is bent to an angle the flexure of the accordion structure almost completely localizes at the point at which it is fastened to the rigid members and it breaks away after a few thousand revolutions of the shaft.

The foregoing are examples of hundreds of ideas which seem on paper to be a solution of universal-joint prob-

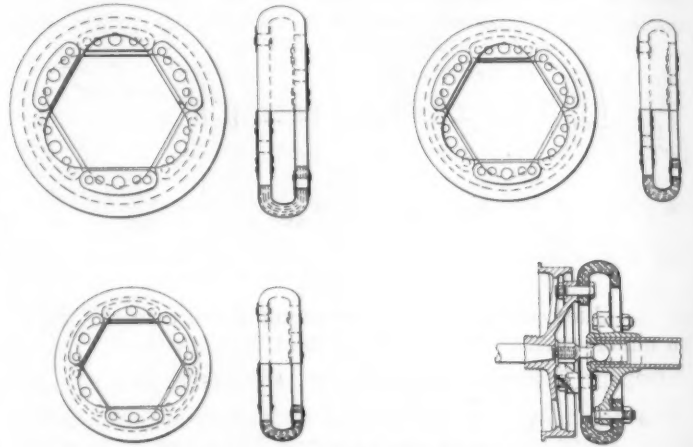


FIG. 12—SIMMS UNIVERSAL-JOINT

This English Construction Is One of Many Attempts To Make a Fabric Power-Transmitting Element More Durable

lems but are of little use in practice. Other types of joint that are out of the ordinary are the Gerome and another, somewhat similar in principle but applied only to constant-angle work, which has been used to some extent in factory line-shafting as a right-angle drive. I do not know the name of the designer or manufacturer of the latter. These are shown in Fig. 11.

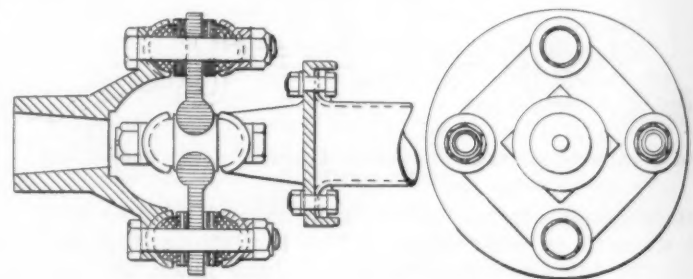


FIG. 13—CLIMAX CORD-TYPE JOINT

Torque Is Transmitted through the Direct Pull of Cords Instead of through Woven Fabric. A Centering Device Is Provided and a Generous Amount of Rubber Around the Bolt-Holes Distributes the Bolt Pressure over a Large Area

Of the many attempts to make the fabric-disc type of joint more durable may be mentioned the Sims coupling (Fig. 12) which received rather wide publicity in the British engineering periodicals a year or more ago. The Climax joint (Fig. 13) is also of the fabric-disc form but differs from others in that it transmits the torque through the direct pull of cords in a construction somewhat similar to that of cord tires instead of through woven fabric. The construction also provides a centering device and a generous amount of rubber around the bolt-holes for the purpose of distributing the bolt pressure over as large an area as possible.

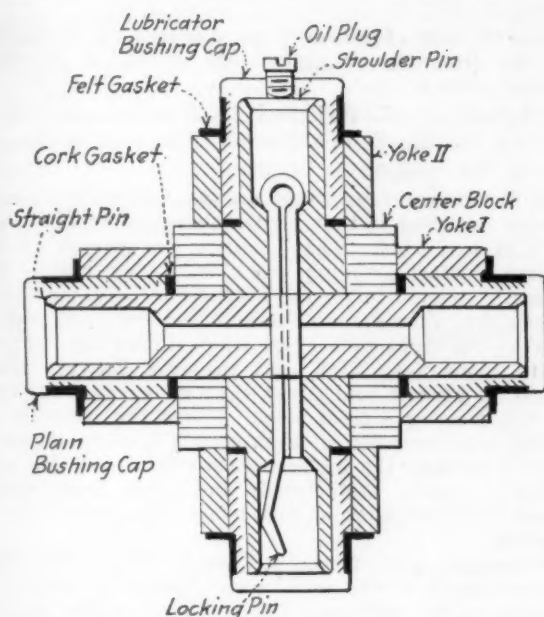


FIG. 14—BLOOD BROS. JOINT INTRODUCED IN 1904. This Consists of Two Yokes Connected Flexibly by a Cross, Is of Compact Construction, Has Large Bearing-Surfaces and Permits of Operation at Large Angles. It Is Oil-Lubricated

PRESENT MAKES OF AUTOMOBILE JOINTS

Having noticed some of the conspicuous examples of theory and type, let us consider briefly the more prominent makes of universal-joint at present offered to the motor-car industry. The Blood universal-joint is one of only two types or makes that I believe have come through the development stage of the motor-car since as early as 1904 without change in the principle of action, such changes as have occurred being only minor improvements in detail as suggested by experience. This is a record

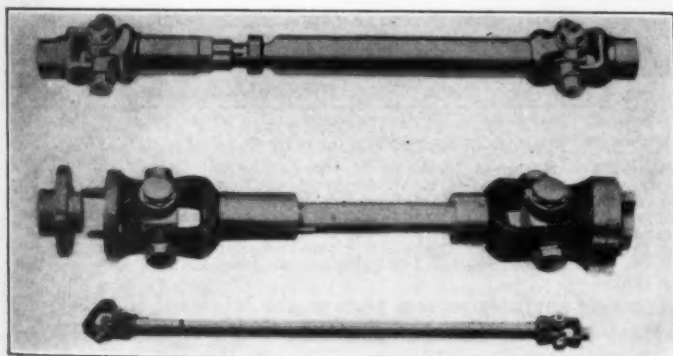


FIG. 15—COMBINATIONS OF BLOOD BROTHERS JOINT WITH AND WITHOUT FLANGE COUPLINGS

that indicates real merit, in view of the great amount of inventive activity in this line during the period mentioned. R. G. Urch, of the Blood Bros. Machine Co., has summarized important advantages of the Blood joint in part as follows:

- (1) The large bearing-capacity in proportion to size of the joint tends to allow compact construction and, in some cases of limited clearance, is often very important
- (2) The construction is very rugged on account of the few parts employed and their generous proportions. Briefly, the Blood joint consists of two yokes connected flexibly by a cross made up of two pins passing at right angles to each other through a square center-block
- (3) The standard design allows operation at large

angles. This result is obtained without in any wise altering the sections or otherwise modifying the design

- (4) Application of the lubricant through a single opening assures a fresh supply of lubricant at each of the four bearings. Fig. 14 shows a cross-section of the joint. Pressure exerted at the oil-hole opening in the lubricator cap will cause the lubricant to fill the reservoirs and then pass the bearing-surfaces before it can be expelled from the joint. The reservoirs are so located that centrifugal force assists in keeping the bearings lubricated and at the same time prevents loss of lubricant. As there is a positive seal under the bushing cap, the only outlet is by way of the bearing-surfaces

Fig. 15 shows several combinations of the Blood Bros. joint with and without flange coupling, brake-drum fitting and so forth.

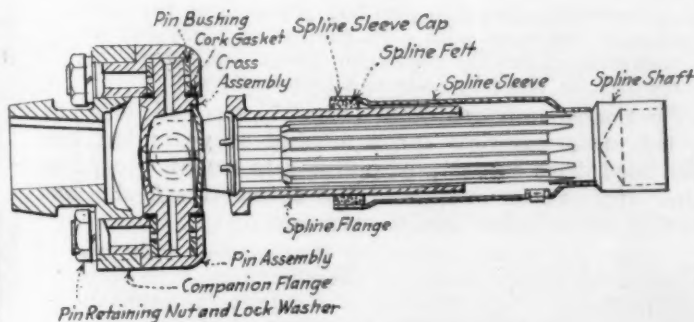
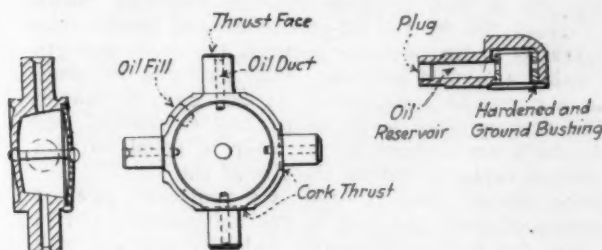


FIG. 16—CLEVELAND JOINT DESIGNED BY F. W. PETERS. The Cross Has an Oil Reservoir in the Center and the Spline Sleeve also Provides Storage for Oil Which is Pumped Back and Forth along the Flutes as the Shaft Works in the Sleeve under Operating Conditions

Although F. W. Peters, who first became known as a universal-joint manufacturer for the motor-car trade through his connection with the predecessor of the Cleveland Universal Parts Co., is no longer connected with this company, his handiwork as shown in Fig. 16 is still in evidence. This joint is described by the company as follows:

Pin.—Cold-rolled steel semi-finished. After the pin is finish-machined the bushing is pressed in place and ground to drawing size square with the shank and at

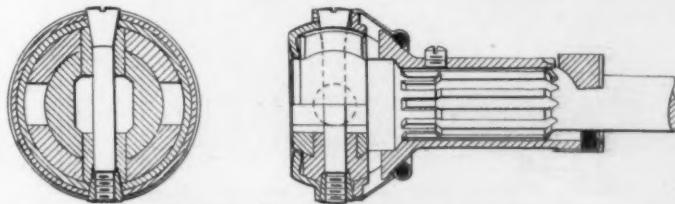


FIG. 17—COOPER BALL-AND-SOCKET JOINT. The Socket Is Slotted to Permit Insertion of Drivers That Extend into the Ball, thus Completing the Rotative Connection between the Ball and the Socket. The Ball Fastens Directly to the Shaft from the Gear-Box or the Differential

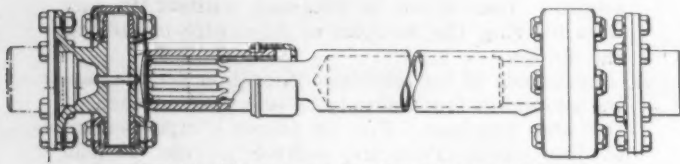


FIG. 18—MECHANICS OIL-LUBRICATED JOINT

The Meeting Edges of the Casing Are Precision Ground and Drawn Tightly Together by Bolts and Nuts. Packing Washers Are Compressed Firmly by Metal Parts on All Sides. The Ends of the Trunnions Are Used for Bearings to Prevent Axial Movement. Every Bearing Operates within the Oil-Chamber and the Spline Slip-Joint Is also Carefully Lubricated

a proper distance from the shank shoulder. Two pins are required for each flange to complete the assembly.

Cross.—Drop forged so as to allow a reservoir for oil in the center. Each cross is capped and riveted to retain lubricant. This is fed through holes in trunnions to the pin and part of the oil is stored in the shank of the pin under pressure due to centrifugal action. It is then pumped into the bushings, which are further fed by the oil-groove around them. The cork seal is under pressure between the cross and pin and makes a perfect packing. Four pins and one cross make a complete replacement at one end; a change can be accomplished in 15 min. The companion and spline-shaft are subject to no wear to speak of and are seldom replaced during the life of the shaft.

Spline Sleeve.—This is used as a protection against adherence of dust and dirt to the spline-shaft and is also used for storing lubricant, which is pumped back and forth along the flutes of the spline under operating conditions. The spline-sleeve is a stamping pressed rigidly over the spline-shaft shoulder.

Assembly.—The two pins are placed over the trunnion of the cross with cork gaskets in place and are then entered into the companion-flange lugs, where they are held in place by nuts and lock-washers.

The Cooper universal-joint (Fig. 17) has had some use in the motor-car field for a number of years but has been used more extensively, perhaps, in machine-tool and other applications outside of the automotive field. Regarding these joints Mr. Cooper says:

They are of ball-and-socket construction, with provision for rotary drive. In the automobile type there is no flange, the center ball of the joint fastening directly to the square or taper shaft of the gear-box or differential, thereby eliminating overhanging weight and tendency toward vibration. The joint proper consists of a ball in a socket that is slotted to permit insertion of the drivers, which extend into the ball, thus completing the rotative connection. The ball takes care of any thrust as well as the weight of the propeller-shaft, leaving the drivers to transmit rotary motion exclusively. Simplicity, minimum number of

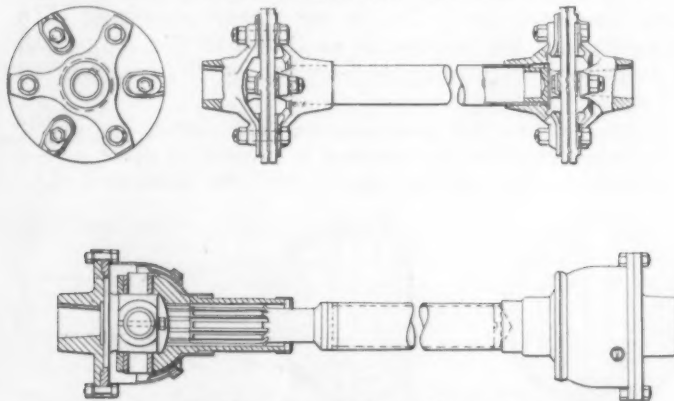


FIG. 19—MERCHANT & EVANS FABRIC JOINT

Permanent Grooves Are Formed in the Fabric Disc, Which Is Held between Elliptical Washers by Force Applied along the Edge of the Washers. Maximum Flexibility of the Discs Is Obtained by Increasing Angle α , in the Upper Left Drawing, as much as Possible and Reducing the Concentration of Bending Stresses

parts, and ease of assembly or disassembly, together with the directness of connections and drive are the notable features.

The Mechanics oil-lubricated joint shown in Fig. 18 is made by the Mechanics Machine Co. and is thus described in the company's bulletin:

The fundamental principle around which this joint has been designed is that oil is the best lubricant for a unit of this kind. The housings are ground on a precision surface-grinding machine, which makes it practically impossible for the surfaces to be other than perfectly flat. The narrow surfaces and the great pressure that the eight nuts exert when drawn into place tend to allow very high unit pressure between the surfaces in contact and cause the two surfaces to fit perfectly, making a tight joint. When the joints are first put into operation at high speeds a slight throw-off of oil through the inside occurs due to the rise of temperature under high speeds and heavy loads and the fact that the joint is completely filled when first assembled.

The washers are surrounded on all four sides by the metal parts of the joint, which makes it possible to compress the packings firmly. This makes them impervious to foreign matter and forces them to retain the oil. We use the ends of the trunnion for bearings to prevent axial movement, and this construction makes it possible to place the packing washers in such a way that any dirt, before it can reach any

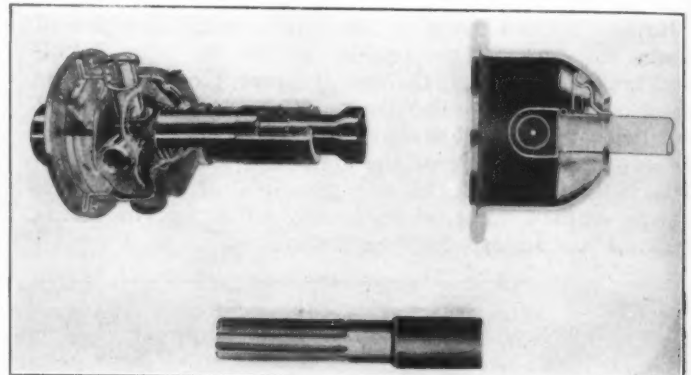


FIG. 20—BOWLING GREEN "OIL-TITE" JOINT

A One-Piece Stamped Housing Is the Load-Carrying Member and Is Provided with an Oil Retainer Held against the Spherical Section of the Housing by Constant Pressure of a Spring Which also Holds a Wedge-Shaped Packing-Gland against the Shaft. The Slip-Spline Has a Close Fit in the Yoke on the Outside of Its Teeth, and the Cork Packing Bearing on the Ground Shoulder of the Spline Reduces Oil Leakage at the Dust-Cap

bearing-surfaces or any part of the lubricant-chamber, must pass through the packing, which is practically impossible. End-thrust is taken on the flat ends of the trunnions against the hardened flat surfaces of the inner periphery of the universal-joint housing. Every bearing point operates within the oil-chamber, where it can be flooded with oil.

The lubrication of the spline yoke or slip joint is also provided for carefully. Because of the self-contained oil-chamber, the lubricant has no chance to be thrown away by centrifugal force.

Two types of universal-joint are made by the Merchant & Evans Co. The one known as the oil type is an all-metal joint enclosed in pressed-steel casings. In the words of M. P. Stoney, mechanical engineer of the company,

The chief point we claim for this type of joint is that heavy oil can be used as a lubricant in preference to grease, due to the patented leather sleeve which clings to the inside of the outer housing. The centrifugal force of the oil keeps this closed. The joint is of conventional pin-and-yoke type which permits

easy replacement of wearing parts without having to replace expensive yokes and other parts. The bushings are held against turning by notching the top of the bushing and peening the metal from the yoke into the bushing slots, on the theory that if a bushing is prevented from twisting it is not likely to become loose.

Regarding the company's fabric universal-joint called the Griptite, Mr. Stoney says:

Permanent grooves are formed in the fabric disc and corresponding washers coincide with the grooves. The flexibility of any fabric disc depends upon the angle π shown above at the left in Fig. 19, the contour of the clamping washer, and the clamping force applied along the edge of the washer. The outline of Griptite washers was developed to attain a maximum

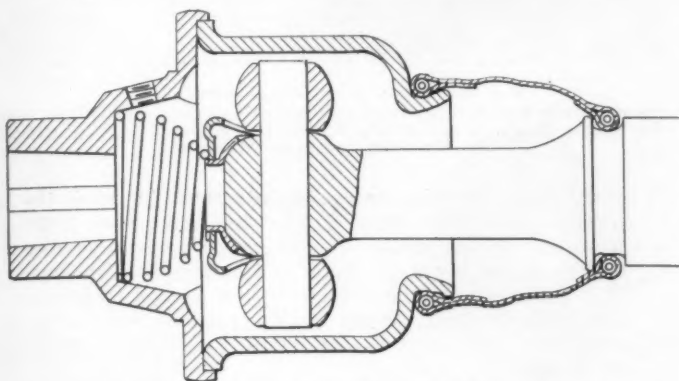


FIG. 21—UNIVERSAL PRODUCTS CO.'S "DETROIT" JOINT Compensation for Length Is Combined with Angular Movement by Balls That Roll in Races, thus Dispensing with a Slip-Joint. Grease Is Used as a Lubricant and Is Trapped on the Bearing-Surfaces by Centrifugal Force. Its Retention Is not Dependent upon Tightness of the Wearing-Surfaces nor upon Packing

of flexibility by increasing the angle π as much as possible and reducing the curvature of the edge from the circular to the elliptical form, thus reducing the concentration of bending stress at the center line between bolts and spreading it out more uniformly along the length of the edge. Due to the large surface-contact with the disc, the clamping pressure along the edge of the washer is much reduced, the washer does not bite into the disc, the bending stress is relieved by working of the fabric under the edge, and the bolts remain tight for a much longer time.

The universal-joints shown in Fig. 20 are described by the Universal Machine Co. in part as follows:

Slip Spline.—The fit of the slip-spline in the yoke is on the outside diameter of the teeth and has a clearance of from 0.001 to 0.002 in., which prevents any hammering and noise. The spline is ground its entire length up to the shoulder, and the shoulder presents a smooth ground surface beyond the teeth of the spline where the cork packing slips. This prevents oil leakage at the dust-cap.

Housing.—This is a one-piece stamping and has its flange formed by folding the metal back on itself, thus giving standard flange thickness. It is the load-carrying member and is $\frac{1}{8}$ in. thick on the small sizes and $\frac{5}{32}$ in. thick on the larger sizes. In torque tests it will withstand from three to five times the torque load of the tubular propeller-shaft.

The inside of the oil-retaining portion of the housing is machined true with the center action of the joint, and the oil retainer, with its cork packing, is ground to a section of a sphere of the same diameter as the oil-retaining portion of the housing. This retainer is held against the spherical section of the housing by the constant pressure of a spring. To prevent leakage between the oil retainer and the shaft, a wedge-shaped packing-gland is provided, and the spring that holds

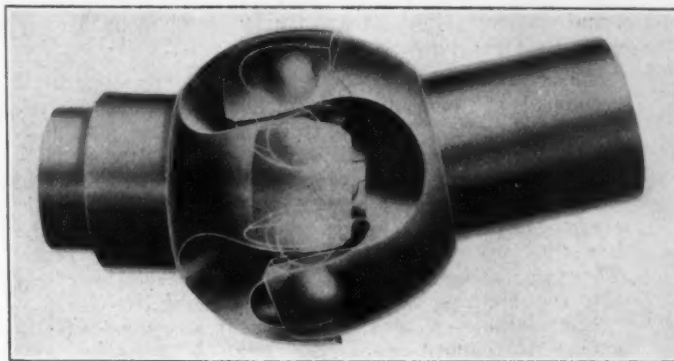


FIG. 22—WEISS JOINT FOR TRANSMITTING CONSTANT ANGULAR-VELOCITY

Six or Eight Steel Balls Inserted between the Jaws of the Two Parts of the Joint Transmit the Torque, Half of the Number in One Direction and Half in the Other Direction. The Balls Roll in Races Milled in the Jaws and, as Angularity of the Joint Varies, the Balls Traverse Only One-Half the Angular Distance Moved by the Jaws, Hence the Balls Always Lie in a Plane That Bisects the Angle between the Shafts and Provide a Uniform Driving Relation

the retainer in place exerts constant pressure against the packing in this gland. The housing oil-seal is a stamping, which is pressed into the joint housing at a 0.025-in. press-fit. This joint, independent of the companion flanges, retains oil.

The one-piece bearing ring is of alloy steel and is machined at 55 to 60 scleroscope hardness after heat-treatment. As there are no bushings, the bearings are made oversize. Woodruff keys lock the two bearing pins in the housing and yoke respectively so that all wear must come on these two pins and in the bearing ring.

The cork packing of the inside oil-retainer operates on the spherical section of the housing, thus forming a ball-and-socket oil-seal. The cork packing in the dust-cap is held tight against the spline by constant spring-pressure, which flattens out and spreads the packing. The outside splash-guard completely houses-in the joint so that road dust and road splash are kept away from the working parts of the joint.

Features of the joint made by the Universal Products

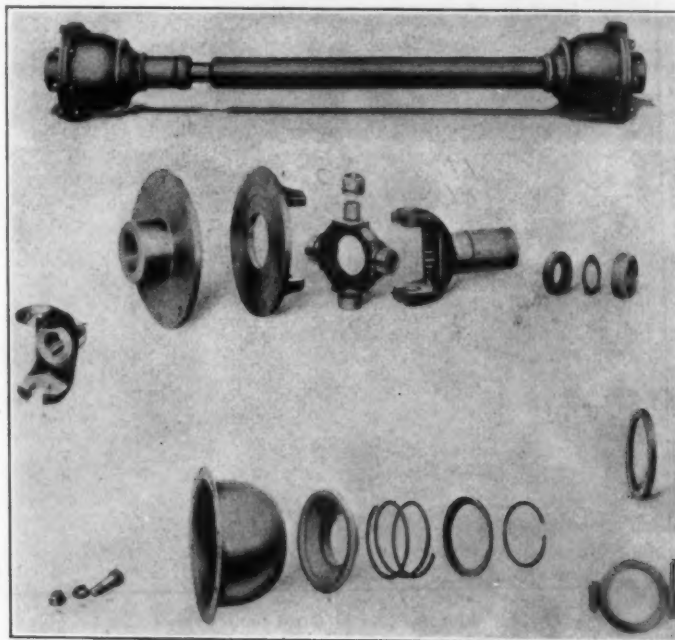


FIG. 23—SPICER TYPE-G JOINT INTRODUCED IN 1904

This Familiar Joint Has Undergone no Radical Change Since It Was First Brought Out. As Shown, It Consists Primarily of Two Yokes Connected by a Cross, All Enclosed in a Hemispherical Pressed-Steel Housing. Grease Is Used as a Lubricant

Co. and shown in Fig. 21 are thus described by Mr. Warner, of that company:

Compensating Balls.—Compensation for length is combined with angular movement in the joint by the rolling of balls in races, thus leaving the propeller-shaft unencumbered by slip-joints. The balls roll with a fraction of the effort required to slide a spline and a difficult place to lubricate is removed. The balls creep continuously into new positions and keep the lubricant thoroughly distributed over their surfaces. They also equalize pressure over the bearing-surface, give free-running operation and have long life.

Lubrication.—A small quantity of any good fibrous grease introduced when the joint is installed and renewed once or twice a season is sufficient, as the lubricant cannot lie in pockets away from the bearing-surfaces but is trapped on the balls by centrifugal force. Retention of the lubricant is not dependent upon tightness of the wearing-surfaces or packing of any kind and is therefore unaffected by normal wear.

The universal-joint produced by the Weiss Engineering Corporation and illustrated in Fig. 22 is designed to transmit constant angular velocity instead of the fluctuating motion transmitted by the conventional joint. The Weiss joint is described more fully in a paper by Edward B. Sturges entitled *A Mechanical Continuous-Torque Variable-Speed Transmission.*⁴ Regarding it Mr. Sturges says:

Where a single universal-joint is used, as in torque-tube drives, the Weiss joint offers a method of obtaining a steady regular motion from the engine to the driving-wheels. Where two joints are now used, one set to compensate the other, a single Weiss joint will often take the place of the two of standard type. In

⁴ See THE JOURNAL, July, 1924, p. 86.

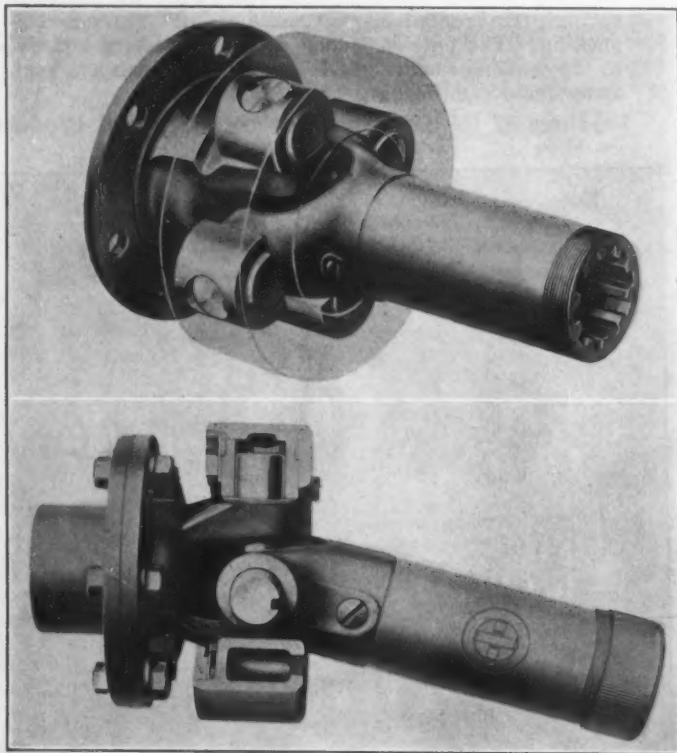


FIG. 24—SPICER TYPE-O OIL-LUBRICATED JOINT
The Usual Two Yokes Are Connected by a Malleable-Iron Ring Cored-Out To Form an Oil-Chamber and Machined for Four Bearing-Blocks, Which Are Sealed at Their Ends by Suitable Gaskets and Held in Position by a Steel Ring Screwed into the Malleable-Iron Ring or by Individual Bearing-Caps. Closure between the Moving Surfaces Is Made by Saucer-Shaped Spring-Steel Washers That Form an Effective Oil-Seal and also Absorb any Wear between the Shoulders of Adjacent Parts

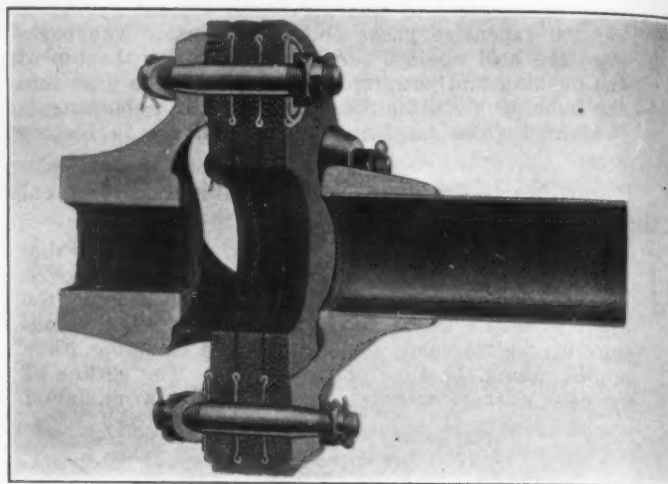


FIG. 25—SNEAD & CO. FABRIC-DISC JOINT
Composition Fabric-and-Rubber Discs of Improved Type Are Held by Spider Washers and Studs Which Are Mounted in Taper Holes To Maintain the Stud Alignment

other cases where a pair of joints must be used, the advantages of this form of joint lie in decreasing the whip and in the ability to use smaller parts because strains in the bearings, shaft and splines are lessened. This joint removes objections to the use of large angles, as the velocity of the shafts remains constant for any angle. The joint has been built for angles as great as 35 deg.

Four, six, eight or more steel balls transmit the torque, one-half of the number taking the drive in one direction and the others in the reverse direction. The jaws of one part of the joint interlock with the jaws of the other part and the balls are interposed in races cut in the jaws. The races are milled so that those in opposing faces cross each other, thus making the races serve as ball retainers. When joined the parts form a sphere with two projecting hubs, one of which connects to the driving-shaft and the other to the driven shaft by spline or otherwise. As the angularity of the joint varies, the balls traverse only one-half the angular distance moved by the jaws; thus the balls continually lie in a plane which bisects the angle between the shafts. This rolling relation of the balls, which establishes between the two parts of the joint a variable plane of contact normal to the angle between the driving and driven members, provides the uniform driving relation that distinguishes this joint. On account of the rolling contact, very little of the lubricant is used and consequently no attention is required for long periods. If the joint should run dry, the results are not likely to be serious.

DEVELOPMENT OF SPICER UNIVERSAL-JOINTS

The first Spicer universal-joint design was patented in 1903 and applied only to the casing. Later patents applied to other forms of casing and to interior constructional details. A familiar joint shown in Fig. 23 is now known as the Spicer Type G, as it is intended primarily for the use of grease as a lubricant. It and the Blood Bros. joint are two of the relatively few motor-car units that have not undergone radical change since 1904. This joint, with its comparatively easy and simple machining, lends itself to great accuracy without high cost. The parts are fully interchangeable, both in the original assembly and when wear makes renewal of worn parts necessary.

Some engineers prefer oil as a lubricant, and to meet this demand the Spicer Mfg. Corporation recently took over the manufacturing rights of F. W. Peters's latest design, which is a modified form of the joint previously

marketed by him as the All-Metal joint. Some further modifications, including S.A.E. standard-spline slip-joints, have been made by the Spicer company. The present Spicer Type O joint, shown in Fig. 24, is a result of the latest developments by Mr. Peters, who has been specializing in oil-lubricated joints for a number of years. It has the usual two yokes which, in this joint, are connected by a malleable-iron ring cored out to form a liberal oil-chamber with suitable recesses, and accurately machined for the four bearing-blocks which, with the yoke pins, are case-hardened and accurately ground. The bearing-blocks are cylindrical but are at right angles to the pin bearing-surface and are therefore self-aligning so far as their relation to the adjacent parts is concerned. They are held in position by a steel ring screwed into the malleable-iron ring or by an individual cap over each bearing-block held in place by two cap-screws, and the joint is sealed at the end of the bearing-blocks by suitable gaskets.

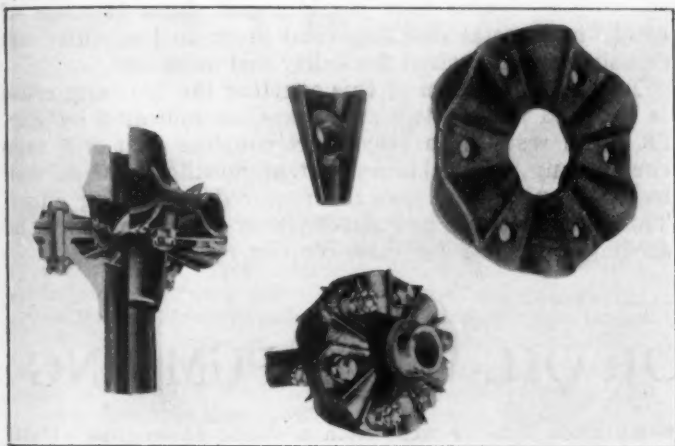


FIG. 26—SPICER-GOODRICH "LONG-LIFE" DISC

An Initial Wave Is Formed in the Fabric in the Process of Manufacture and the Conical Openings Are Filled with Live-Rubber Cores. Washers of Special Shape Help To Support the Flexible Members, and the Compression Members Aid Substantially in Carrying the Driving Stress

The feature that gives this design an important advantage is that the closure between the moving surfaces is made by saucer-shaped spring-tempered steel washers, which have been found to provide a perfect oil-seal not only when new but after service equivalent to the life of the average car. These washers also serve the important function of absorbing any slight wear between the shoulders of the adjacent moving parts, thereby avoiding the development of side play or rattle. The use of this saucer-shaped steel washer seems to have solved the lubricant-retaining problem.

NON-LUBRICATED FABRIC JOINTS

Motor-car engineers have been much interested, at least academically, in the idea of a universal-joint that would not require lubrication or other attention during the life of a car, or for a considerable percentage thereof. Leather discs were used to a limited extent as early as 1907 or 1908. Later, discs were cut from rubber belting but without great success. Then the British engineer, Edward J. Hardy, conceived the idea of building fabric discs especially for the purpose, and of staggering the weave of the fabric to give more uniform distribution of the load throughout the disc. The American rights under his patents were taken over by the Thermoid Rubber Co. and large numbers of Thermoid-Hardy discs have been used in this Country. Since the introduction of this

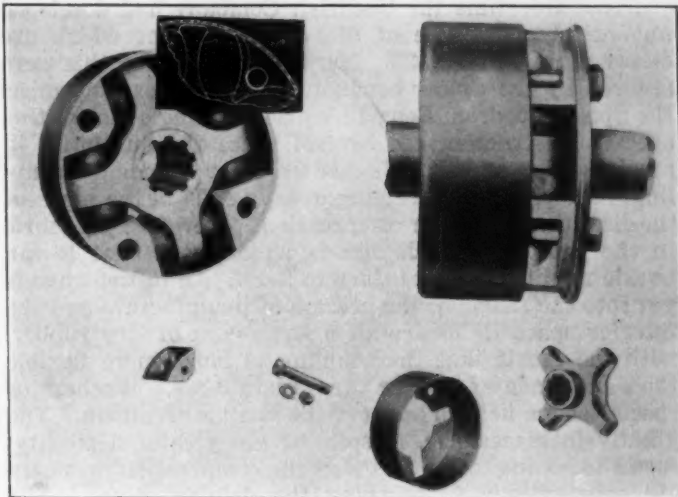


FIG. 27—SPICER CUSHION-BALL JOINT

The Splined Cross Is Carried on Either the Driving or the Driven Member and Its Arms Are Recessed to Receive Rubber Balls. The Companion Flange Carried by the Other Driving or Driven Member Has Bolted To It Four Triangular Blocks Similarly Recessed and Surrounded by a Sheet-Metal Housing. Eight Balls Are Held in the Opposed Recesses and Four Carry the Load in One Direction and the Others in the Opposite Direction. No Lubricant Is Used. In Operation at an Angle, a Slight Rolling Motion of the Ball Permits of Free Universal Movement

type of disc great strides have been made in the production of both fabric and rubber compounds for the purpose, and the better makes of plain discs today are much more durable than even the Hardy discs were at the time of their introduction.

One of the companies responsible for this improvement in fabric discs is the B. F. Goodrich Rubber Co., whose discs were used extensively by Sneed & Co. About 2 years ago the Spicer company took over the propeller-shaft rights of Sneed & Co., who were building joints of the type shown in Fig. 25, with studs mounted in taper holes in the spiders to maintain the stud alignment and having generous fillets on the edge that would not cut the disc.

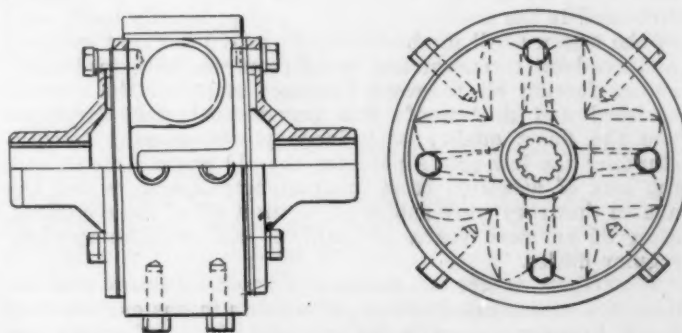
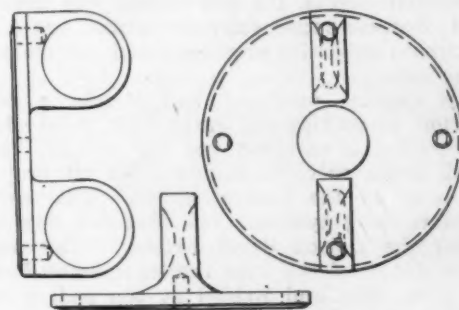


FIG. 28—SHORT-COUPLED MODIFIED FORM OF CUSHION JOINT

The Four-Arm Cross in Fig. 27 Is Replaced by Two Two-Arm Yokes. This Construction Results in a Very Short Coupling That Will Take Care of the Usual Amount of Misalignment and Small Angles and Give the Required Cushioning Effect

About this time the Goodrich Company had developed an entirely new type of disc the details of which are shown plainly in Fig. 26. Marketing rights for this were secured by the Spicer company and it is now known as the Spicer-Goodrich Long Life disc. A single disc of this special construction has several times the durability in service of a corresponding two-disc or three-disc coupling. The plain-disc coupling usually fails in the parts of the discs that are under compression. Therefore the fabric in the Spicer-Goodrich disc is so disposed that it can buckle readily without injury to itself. An initial wave is put into the fabric in the process of manufacture and the interior space is filled with a large core of live rubber, with the result that the coupling is much more flexible than one made of two or three plain discs. Washers of special shape help to support the flexible members. The greatly increased life, in spite of the greater flexibility, seems to be due to the fact that the compression members aid substantially in carrying the driving stress. The cushioning effect of this type of drive is much greater than that of the plain-disc drive. The Long-Life disc drives are showing more than 50,000 miles of service without attention.

THE NEW CUSHION-BALL UNIVERSAL-JOINT

Another comparatively new product is the Spicer cushion-ball universal-joint, which has been developed entirely within the Spicer organization. As shown by Fig. 27, a cross is carried on either the driving or the driven member. The arms of the cross have recesses to

receive rubber balls. The other driven or driving member carries a companion flange to which are bolted four triangular-shaped metal pieces and a sheet-metal housing. The triangular pieces also have recesses to receive the balls and the whole is assembled as shown. The complete coupling includes eight rubber balls, four of which carry the load in one direction and the other four in the opposite direction. When operating at an angle there is a slight rolling motion of the balls in the recesses, thus permitting of a free universal movement. This type of coupling is giving good service in propeller-shaft applications where the angle is not great and in all classes of normally straight-line drive.

An especially important field for a coupling of this type is the gasoline-electric service, in which the cushion-ball joint between the engine and the generator completely absorbs the variations in the speed of the crankshaft between explosions and permits the generator armature, which acts as a flywheel, to rotate at comparatively constant speed. This relieves all the parts of serious strains that would result from the use of solid or all-metal couplings and gives to the entire assembly a much-desired flexibility and quietness.

In a modified form of this coupling the four-arm cross is replaced by two two-arm yokes, as indicated by Fig. 28. The result is a very short coupling that will take care of any reasonable amount of misalignment as well as small angles and give the required cushioning effect. This is an entirely new development and promises to be an important one for close-coupled requirements.

OIL AND GAS ENGINES FOR OIL-WELL PUMPING

THE steam engine, devoid of a governor, was the first mode of power used in the early days for pumping oil. This power was unreliable and expensive, as a man or engineer was obliged to be with the engine constantly. Later on in the oil business, and in the early history of the internal-combustion engine, the gas engine was developed so that it would operate successfully on natural gas. Previous to 1888, internal-combustion engines would operate on manufactured gas only.

The early engines produced had simply a bed-plate, cylinder, piston, connecting-rod, crankshaft, flywheels, a one-way clutch pulley, a cast-iron pot for cylinder lubricator with a small brass valve to regulate the oil drop, and a hard-grease cup on the connecting-rod. This constituted the entire lubricating system. The first few engines were put out with the Edison liquid battery. This was soon abandoned in favor of the tube igniter composed of $\frac{1}{4}$ -in. pipe about 5 in. long and welded at one end, a cast-iron chimney and a small brass jet producing a small flame to heat this tube igniter. Contrast this with all the refinements embodied in the engines of today; strong, heavily built, most of the engines will produce from 50 to 100 per cent overload and are built to run at any speed required; with feed lubricators forcing oil to every bearing; many of the engines enclosed and dust-proof; fine heat-treated steel forgings; and the finest quality of refined cylinder-irons. Notwithstanding the low prices paid for the old engines mentioned, the lack of attention from inexperienced operators and the abuses that they were subjected to, most all of these engines, after 25 or more years, are still in use, performing their regular duties.

I attribute to the oil producer's resourcefulness and his inventive genius many of the refinements in gas engines that finally brought success in the pumping of oil wells with gas engines. Following the introduction of the gas engine for pumping the individual well, came the push-and-pull power, then the geared and then the band wheel power arranged to

pump from 8 to 30 wells with a single gas-engine. Until very recently the bulk of production was obtained from the great number of small old wells in all fields. Many thousands of these small wells would have been abandoned many years ago if it had not been for the economical use of the gas engine.

INCREASED DEPTH OF WELLS

In the early period of the oil business, the depth of the oil well was from 800 to 1800 ft.; a 2000-ft. well was considered a deep and heavy one. Today wells of 2000 ft. are considered shallow wells; many wells are 5000 ft. in depth. Much larger and heavier materials are now used in the well, demanding heavier pumping equipment, longer and heavier pumping-rods, as a greater volume of fluid is to be handled, making larger and better equipped power doubly necessary.

The pumping of the well is of little moment; the extreme test comes when the casing, the rods or tubing has to be pulled. The time required to change rods and tubing means much. A powerfully built gas engine will perform this service in the quickest possible time.

If the drilling contractors, as well as the large companies that do their own drilling, would once decide definitely that the drilling crew must drill with gas or oil engines, or be eliminated, the gas and oil drilling-engine would quickly become an established fact. In the eastern fields, Ohio and West Virginia, where wells from 2000 to 4000 ft. in depth are drilled with gas engines, a saving of from \$600 to \$1,000 per well on fuel used is effected.

The gas engine for pumping oil wells is the cheapest power unit that I know of in the world. With this type of engine, the only expense is for maintenance, lubricating oil, depreciation, and labor. I have placed no value on the gas used, because in most cases gas is allowed to go to waste; should a valve be placed on the gas used, it would be but a small item.—Pat Shouvin in a paper presented at a meeting of the American Petroleum Institute.

Discussion of Papers at the Semi-Annual Meeting

THE discussion following the presentation of three of the papers at the Semi-Annual meeting of the Society held at French Lick Springs, Ind., last June is printed herewith. The authors were afforded an opportunity to submit written replies to points made in the discussion of their papers and the various discussers were provided with an edited transcript of their remarks for approval before publication.

For the convenience of the members a brief abstract of each paper precedes the discussion, with a reference to the issue of THE JOURNAL in which the paper appeared so that members who desire either to gather some knowledge of the subjects covered without referring to the complete text as originally printed or to refer to the illustrations that appeared in connection therewith can do so with the minimum effort.

THE AUTOMOTIVE WORM-GEAR

BY L. R. BUCKENDALE¹

ABSTRACT

PROGRESS in the development of automotive worm-gearing is interestingly outlined. Previously to 1912, American experience had been limited almost exclusively to the industrial form, generally of the single-thread type. Introduction of the motor-truck required a worm for the final-drive but one having entirely different characteristics from that of the industrial gear. Experience in designing these was lacking, however, as was also the special machinery to produce them. In 1913, machinery was imported from England and since that time development has been rapid.

First efforts were devoted to simplifying the design of the axle as a whole, studying the problem of getting lubricant to the bearings, heat-treating the parts, and improving the materials of construction.

Passenger carrying brought new requirements in the way of higher speed, greater acceleration, less reduction in the rear axle to give more miles per hour with a given engine, and quietness; but, because the conditions under which they operate are better, motor-coaches allow the use of the underslung worm, the propeller-shaft brake and a lower chassis, with the accompanying lowering of the center of gravity of the vehicle and, consequently, an increase in stability.

In 1917 and 1918, study of the mathematical analysis of the principles of tooth contact and angular velocity brought new designs in tooth forms, which are discussed. The salient advantages of the worm-drive are said to be (a) silence, (b) the fact that it retains its silence throughout its life, (c) its ability to resist shock loads without damage, and (d) its contours, which may be generated with a grinding-wheel after all the other operations have been performed; consequently, a high degree of accuracy in tooth profile, lead angle and tooth spacing may be maintained. Freedom from knock is attributed to the obliquity of approach of the teeth, to the greater areas in contact, and to the low resonant qualities of the materials used.—[Printed in the June, 1926, issue of THE JOURNAL.]

THE DISCUSSION

JOHN YOUNGER²:—One omission has been made by Mr. Buckendale. He has traced the history of worm-

gearing largely from the point of view of the truck and of the motorcoach, but the development of worm-gearing for passenger-cars can go back to 1900. About 1905 or 1906, I had the pleasure of driving at 75 m.p.h. a passenger-car equipped with worm-gearing. At that time the Dennis Company was manufacturing worm-gearing with the overhead worm. Another school of thought, as Mr. Buckendale has brought out, had regard to the hour-glass type of worm as used by Lanchester. Both types were very successful. At that time we had case-hardened worm-spindles and the little scale on the casing was removed by sand-blasting or by scraping with a hand-tool; grinding was used. Today, worms are ground; the worm-wheel then was left as it came from a somewhat rough cutting. Worm-wheels were not reamed as they are today. Yet we were able to get speeds up to 75 m.p.h. and possibly more. In England today about 12 per cent of the builders of passenger-cars equip their product with worm-drives; but the curious thing is that a much larger percentage of so-called quality cars are equipped with worm-drives. I am very enthusiastic about the possibilities of worm-drives in passenger-cars.

CHAIRMAN C. D. MCCALL³:—Have you found the present type of worm any more sensitive to adjustment than the bevel-pinion?

L. R. BUCKENDALE:—Every portion of the straight-type worm-gear has its endwise axis identical with that of every other portion. There is no sensitivity whatever. It can be adjusted endwise within the range of the teeth that have been cut. As the material of the worm is given all the properties to resist wear, it maintains its correct initial tooth-contact.

A MEMBER:—Two camps exist in the manufacture of gearing, one, which has existed for from 5 to 8 years, being in favor of the spiral-bevel gear, the other being in favor of the worm-gear type. In the first case, the driving-pinion is located radially; in the second, it is located tangentially. Then along comes the hypoid-gear and moves out of the radial position and near the tangential position. We have, therefore, to deal only with a question of degree. The time will come when it will be difficult to distinguish between the two; they will be almost the same. The inexplicable thing is why, in one camp, steel is used for both the driving and the driven

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² M.S.A.E.—Editor and publisher, *Automotive Abstracts*; professor, industrial engineering department, Ohio State University, Columbus, Ohio.

³ Chrysler Corporation, Detroit.

gears, while, in the other, the driven gear is invariably made of bronze.

All gears are subject to fatigue failure. All gears fail sooner or later; when is only a question of time. Gears, in fact, should be designed with the factor of safety sufficiently low so that the weight of the gears will not burden the axle with undue weight. If a gear does not show pitch-line erosion at any mileage, it indicates that it could be made lighter. To have the gear outlast the car is unnecessary.

The fact remains that, in the case of worm-gears, bronze has been slavishly adhered to, in spite of the fact that its tensile strength is hardly in excess of 40,000 lb. per sq. in., while, in the case of hypoid-gears, steel is being used having a tensile strength of certainly not less than 120,000 lb. per sq. in., and more if the steel is case-hardened. We should bear in mind that, in the case of bevel-gears, we have nearly true rolling, whereas, in the case of worm-gears, sliding predominates. Bronze is the better material to resist sliding motion.

MR. BUCKENDALE:—I am trying to figure out whether the last speaker is in favor of putting steel into worm-gears or bronze into the bevel set. So far as slavish adherence to one type of gearing is concerned, that is not true. We have tried various kinds of material not only in experimental sets but also in a large number of experiments. We have never used case-hardened steel, because to get a job that would run after the carbonizing, hardening and the like have been finished would be difficult. With regard to using non-ferrous metals in the bevel type of gears, we happen to be in both camps, I have run in my own car a gear having the ring gear of the bevel made of duralumin. I took it out because I feared the teeth would be broken out when the car was running in heavy mud; but nothing happened. It ran quietly for about 15,000 miles.

MR. YOUNGER:—The strength of bronze was mentioned as being 40,000 lb. per sq. in. My own impression is, that in the heat-treated state it is much greater. What is the strength of a typical bronze alloy?

THOMAS JEACOCK:—For some time chilling has been recognized as improving the physical properties of tin bronze. I refer only to tin bronze because it is the bronze we find best applicable for gear-blanks because of its bearing quality. While bronzes often possess a higher tensile-strength, they lack the bearing quality of tin bronze. By chilling we increase the physical properties of tin bronze over an unchilled casting of like alloy. Foundry practice for years has been to put a chill in the mold on some particular part of the bronze casting, the physical properties of which it is desirable to raise. If a bar 2 in. square, such as is shown in the upper drawing of Fig. 1, is chilled on the top, and because we are talking about gears, we let it represent a gear section, we have a chilled area where the metal is refined because of the application of the chill to that part of the casting.

In the hobbing of the gear we cut out the very best part of the metal that we have chilled, because we have a ring and do not know how to get the chill all through it. If the bar is cut into four pieces, making four bars each 1 in. square, one of their most interesting physical properties is the resistance to impact, or the strength of the bronze to withstand constant pressure, so that gear-teeth will not break off or pull out.

If we were to make a standard impact-test, as has been done in the Pierce-Arrow plant, we should find that

the test on bar No. 1 would show 26,640 lb. You will notice that this is right under the chill. A standard impact-test on bar No. 4 would show 1404 lb. I am not referring to any particular alloy, because these figures are merely comparative, based on the alloy. The maximum impact is at the root of the tooth. You do not care what the resistance to impact is anywhere else, if you have cut the chill out; it is gone, and the remaining bronze tests 1404 lb. and that is all. Our company has developed a die-casting process for chilling gear bronze on three sides as shown in the lower view. After the casting has been made the whole casting is chilled; it is chilled straight through, and this figure of 26,640 lb. extends through. The tensile strength of the bronze ranges from 26,400 to 5720 lb. in bars No. 4 and No. 1 respectively.

CHAIRMAN MCCALL:—What is its Brinell hardness?

MR. JEACOCK:—In the No. 1 bar the Brinell hardness is about 100 and in the No. 4 bar, about 70. By using the three-side chill process, the hardness would run constant through the piece.

JOHN MCGEORGE:—I wish to take exception to Mr. Buckendale's statement that this investigation was begun in 1917. I think he will find the date is much farther back. Even back in 1888, I built some special machinery in which a worm-wheel that was very carefully cut in steel was used for driving. When we put it into operation, we could not keep it from furring. The difficulty was found to be not in the worm-wheel, which ran perfectly, but in the thrust-bearing. We did not have the beautiful bearings that we have now, but when we made a conical thrust-bearing the difficulty disappeared.

At that time I had a small pamphlet on worm-gearing in which a number of investigations were outlined and no successful worm-gearing was found to have been made with a helix angle of less than 18 deg., the assumption being that the helix angle and the pressure angle were the same.

I very carefully kept the worms over 22½ deg. and on the whole was fairly successful. Bearing that experience in mind, about 1908 I first built a worm-driven machine. The requirements of the gear-ratio compelled me to increase the helix angle to about 30 deg. I remember a statement in that old pamphlet that the ideal angle was 45 deg., but I built mine at 30 deg. and they were successful. The worm-wheels were of bronze and the worms were of steel.

Some time afterward I read of some experiments that had been made by the Brown & Sharpe Mfg. Co. This was soon after the great progress that had been made in England with the D. V. Brown worms and, incidentally, with the Lanchester. The Brown & Sharpe worms were very efficient, 96 to 97 per cent, if my recollection is correct. I saw a copy of the drawings of the Brown & Sharpe worm and found, very much to my surprise that it was almost identical with the worm that I had built.

Then I began to investigate the angles and found that my spiral-angle of 30 deg., when it was resolved into the angle of pressure at right angles to the surface of the worm, was barely 45 deg., apparently the most efficient point I could get.

I found afterward, when I got all the particulars of the D. V. Brown worm, that mine, again, were almost identical with them. The Brown & Sharpe worm and the D. V. Brown worm were almost identical.

MR. BUCKENDALE:—I did not mean to give the im-

* President, Buffalo Bronze Die Cast Corporation, Buffalo.

* M.S.A.E.—Technical adviser on special engineering work, Oakland Motor Car Co., Pontiac, Mich.

pression that the investigation was begun in 1917. Investigations have gone on for many years, many of them before I was born. I was merely pointing out where the effect of that investigation occurred in the volume production of automotive gearing.

In the automotive field, we ordinarily think in terms of ratios. Successful ratios are operating today that range from a 2-to-1 reduction, that is, two revolutions of the worm-shaft to one of the wheel, up to about 15 to 1. That is about the ordinary range that I am familiar with in practice today.

N. H. SCHICKEL⁶:—I think Mr. Buckendale has overlooked the fact that worm-drive trucks were produced as stock products by several American firms considerably earlier than 1912. The Franklin Company built worm-drive trucks during 1909 and 1910, and I think they built them several years before that. The Pierce-Arrow Company also built worm-drive trucks about the same time.

C. S. CRAWFORD⁷:—The high point in Mr. Buckendale's paper is that we should not confuse old worm-gear problems with the new art. My experience with worm-gears in the last 2 years has been such that I should like to forget everything that has ever been done before. I believe the type of worm and gear construction that the Timken-Detroit Axle Co. has developed is an entirely new art in many respects. If consideration is seriously given to the lowering of the center of gravity of an automobile, it is the only present type of drive to consider, for it will allow the lowest possible center of gravity.

So far as our company is concerned, we have never at any time considered the worm-drive axle because it was worm-driven. We have had only one thought in mind and that was the lowering of the center of gravity to obtain higher safe road-speeds, make faster turns and get better equalization of weight on the wheels when the brakes are applied suddenly. We are very fortunate, of course, in having an axle that, we believe, will outlive by far any bevel-gear-drive axles.

A MEMBER:—Mr. Buckendale has said that they used a ring. What is the reason they did not continue using it? We had experience recently with Tom Milton's supercharger in which a 10,000-r.p.m. pinion ran about 28,000 r.p.m. This pinion was meshed to clash gears having about $\frac{3}{4}$ -in. faces made of duralumin. The tooth pressure on those gears was very light. After the gears had been used for about 5 or 6 months, the teeth all began to take an angle over to one side as if the pressure on them had been very great.

In some of the other superchargers in which we did not use so large an impeller that was not the condition. I have wondered whether the angularity that the teeth had taken was due to the fact that the teeth had been peened over by a certain rolling action. I thought possibly the same condition might occur in the ring gear on account of the higher pressure, even though the speed was less.

MR. BUCKENDALE:—I believe the experience just cited was due to an extremely high angular-velocity of the teeth in question. An enormous number of tooth contacts in a given time and the variations in angular velocity of the gearing, which at ordinary speeds are a very minor matter, give very high variations in loading or hammering at high speeds, which cause a peening

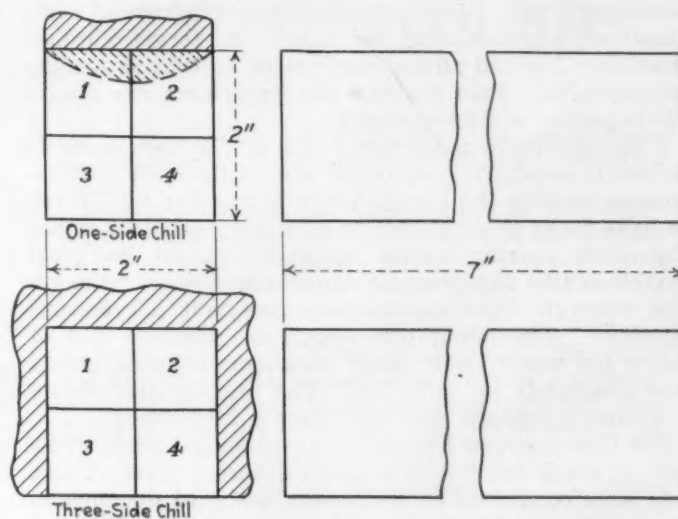


FIG. 1—TWO METHODS OF CHILLING A BRONZE CASTING
In Hobbing a Gear Where the One-Side Method Illustrated in the Upper Drawing Is Employed, the Chilled Metal Is Cut Out Since the Chill Does Not Extend through the Entire Casting. With the Three-Side Method Shown in the Lower Drawing, the Whole Casting Is Chilled

action. On the gearing we have been discussing the angular velocities are low, so that their only effect is in the form of noise or in the continuing impact's being audible. In the effect on the material itself, the torques and powers are enormous when compared with the slight reverses that occur. In our experiment on the gravity metal, extremely heavy machines were used, that is, double-deck-type motorcoaches operating at vehicle speeds averaging 18 m.p.h., or more. In that case we did not seem to get the desirable bearing-properties we wanted. This experiment is still being carried on to some extent. That was our primary reason for seeking material having the most desirable bearing-surface and resisting surface and was our biggest problem. Getting the necessary strength into the tooth, in our case, is not a difficult problem, while in your case it was.

A. L. STEWART⁸:—Mr. Buckendale did not state in his paper that the worm-drive can be used without sacrificing road clearance. I should like to ask whether that applies to a passenger-car. If so, assuming that the diameter of the bevel ring-gear is 11 in., what would be the dimensions of a worm-drive that would allow the farthest point of the worm to be not more than $5\frac{1}{2}$ in. from the center of the axle?

MR. BUCKENDALE:—You are speaking of the gear, I believe. You have a housing to consider. In the construction of the bevel-gear housing, the geometry of the gear requires the facing to be forward and that requires some room. In the other gear, you have merely the worm housing and its flange to consider. Relative factors of safety are the primary consideration. Today, if we use the factors of safety that are being used on very high-speed machines, such as motorcoaches, and use the same relative speed-factors, pressures and the like, we shall have a worm-gear set very much smaller than that which is being used; but we are in a field where our experience is somewhat limited and naturally are playing safe. We are holding down the gear surfaces, areas and pressures purposely until we learn what the limits are. That was true of the bevel-gear. We began with large bevel-gears and continued until the mountings and the remainder of the problem had been developed. We did not make the gearset as small as we are making it today.

C. L. SHEPPY⁹:—Our company has been a pioneer of worm-gearing and, like all pioneers, has had trouble and

⁶ M.S.A.E.—Dearborn, Mich.

⁷ M.S.A.E.—Chief engineer, Stutz Motor Car Co. of America, Inc., Indianapolis.

⁸ M.S.A.E.—Chief engineer, Gleason Works, Rochester, N. Y.

⁹ M.S.A.E.—Chief engineer, Pierce-Arrow Motor Car Co., Buffalo.

necessarily has gained considerable experience. Mr. Crawford has said that he wanted to forget all past practices; I would advise him not to do that in designing anything. Past practice and experience are always a safe guide for future design.

I should like to point out a few of the high spots in the worm-gear drive on truck and motorcoach installations as used by the Pierce-Arrow Motor Car Co. First, we have found that the factors of safety should be ample. The worm-gearing center distances should be great enough so that the pressure due to the torque of the engine through transmission reduction will not become abnormal. The lubrication should be adequate and of course the worm itself under maximum stresses should have practically no deflection. The bearing also should be of ample capacity and have proper lubrication.

The Pierce-Arrow Company has conducted break-down tests on truck worm-gear axles of different types. These tests were conducted on a specially designed dynamometer capable of maintaining the maximum load for long periods of time without any shutdown. The effect that inadequate bearings have on the life of the worm and worm-wheel is indeed surprising. If the bearings are not ample to take the thrust and radial load, the worm and worm-wheel will fail under heavy service. On the other hand, if the worm itself is of sufficient cross-section so that it will have practically no deflection at maximum load and lubrication is ample, long life can be expected. In running break-down tests under full load, actual service conditions on the road under maximum-load conditions should be duplicated as nearly as possible. If under tests or service conditions the temperature rises abnormally, the oil-film will be broken down and the worm and worm-wheel will be destroyed. Some of the original worm-gear trucks built by the Pierce-Arrow Company are still operating with the original worm and worm-gears. These original worm-gears were imported from England from the David Brown Co.

The F & J type of tooth gives a very different tooth-contact than the involute type. After completing our tests on the worm-gear installations, we plotted charts showing the surfaces that had actually been in contact and compared the two charts. The greater bearing-surface that shows up in the F & J type as compared with the involute type is surprising.

As to the passenger-car type of worm-gear, our experience 12 years ago was with the worm-gear on top, not underslung. I hope that some day some institution or organization in this Country will develop a dynamometer which will be available to manufacturers of worm and bevel-gearing by which the maximum torque can be put through the gears for an indefinite period and a careful study can be made of the efficiency of all types of worm-gear, hypoid-gear, spiral-bevel gear and the like. To make these tests of any value, they should be conducted of course to represent as nearly as possible the conditions under which the several designs operate in service. To test a worm-gear axle on a test-stand under full load where the oil temperature will probably rise abnormally high, whereas under actual operating conditions on the road it will never reach these abnormally

high temperatures, is not fair. If tests are conducted an attempt should be made in all cases to maintain an oil temperature approximately equivalent to that of the operating condition on the road; otherwise the results will be a sad disappointment.

In some of our tests we tried to run without having any means of cooling the lubricant in the axle bowl. After the temperature has risen to 200 deg. Fahr., it goes up very rapidly. On the other test in which we cooled the oil in the axle bowl, we could maintain a practically constant temperature that never went dangerously high. Some of the above mentioned tests were run for 500 hr. continuously under maximum load.

I am pointing out all these facts and giving you these suggestions because I feel that considerable work on worm-gearing for passenger-cars remains to be done. Some of the problems in worm-gearing may have been overcome but others call for solution. If you make your own worm-gear axles, you must consider the factors I have pointed out, that is, you must have proper factors of safety and try to make the axles neither too small or too light. In other words, $\frac{1}{2}$ -in. greater center-distances would be worth a large sum of money to you.

MR. CRAWFORD:—I should like to correct an impression with regard to forgetting the past. Many of you have had experience with worm-drives and have had trouble with them, especially in the earlier days. We should forget the prejudices that they may have produced. The best thing that any engineer can do is to remember his troubles but he should not let them prejudice him.

MR. BUCKENDALE:—In designing axles for any type of vehicle too much emphasis cannot be placed on the question of deflection, that is, displacement under load. When a set of gearing is designed, cut, and put on a matching-stand, the tooth contacts are judged while it is held in enormous bearings with no possible deflection. In many cases the loads do not compare with those the gearing will receive in the vehicle. The tooth contact is criticised when the gear is put in an axle designed with economy of weight and the minimum of bearings and is allowed to deflect more or less and the same fundamental characteristics are expected from it that were obtained on the stand. The same relation of gearing must be maintained under the load that you are judging to be within your calculation. That is absolutely fundamental in worm, bevel, hypoid, or any other type of gear.

A MEMBER:—Mr. Crawford has said that his chief interest in the worm-gear axle is the possibility of lowering the body and reducing the over-all height. I am assured by the chief engineer of a company having a large production that he has not had unusual difficulty in getting the over-all height down to 69 in. from the ground with the standard spiral-bevel rear-axle. So, some possibilities still remain.

MR. CRAWFORD:—On the other hand, I do not believe that the particular design referred to has a cushion 14 in. high and a head clearance of $37\frac{1}{2}$ in. To obtain a very low center of gravity, the frame and floor must be dropped; and it should be done without sacrificing passenger comfort.

ANTI-FREEZE SOLUTIONS AND COMPOUNDS

BY H. K. CUMMINGS¹⁰

ABSTRACT

THE effectiveness and the advantages and disadvantages of various substances and compounds that are used or offered in the market for use in the radiators of automotive vehicles as anti-freeze materials are discussed. These include alcohols, glycerine, salts, oils, sugars, and glycols.

Properties affecting the suitability of a material or compound, or solutions of them with water to afford protection against freezing at atmospheric temperatures that are likely to be encountered are their heat capacity, freezing-point, boiling-point, specific gravity, viscosity, volatility, solubility, tendency to decompose at the boiling-point, inflammability, corrosive action upon metals, tendency to attack rubber, general availability, and price.

The freezing-points of solutions of different materials vary widely at the same concentrations, or proportions to water, and also with variation of their concentration. Determinations of the freezing-points as made at the Bureau of Standards are given in charts. The freezing-points also vary with the specific gravity, and determinations of these points are given. Large differences exist in the initial viscosity of water, oils and aqueous solutions of glycerine, glycol and honey, and in the rate of increase of viscosity with decrease in temperature. Curves based on viscosity determinations for such liquids over a wide temperature range are shown.

Solutions of the salts of sodium, calcium and magnesium have much lower freezing-points than the sugar solutions and at much lower concentrations and afford protection at considerably lower minimum temperatures. Glycerine and ethylene glycol give protection at almost as low minimum temperature as calcium chloride, which is the most efficient of the salts, but only at about double the concentration. Wood alcohol and denatured alcohol rank next in effectiveness, at concentrations of 50 and 70 per cent by volume, and resist freezing at a temperature of -40 deg. fahr.

Alcohol has several virtues as an anti-freeze material but boils at 172.4 deg. fahr., which results in its rapid loss by evaporation and limits the use of devices for maintaining high engine-temperature. Kerosene, on the contrary, has a high boiling-point that may result in serious overheating of the engine in mild weather. Other objections to its use are its odor and inflammability and its action upon rubber. Lubricating-oil and the solutions of sugar have high viscosity at low temperatures, which causes slow circulation of the cooling medium unless the passages in the cooling-system are ample.

Commercial distilled glycerine that is free from electrolytes and is practically neutral has no corrosive effect on metals and does not injure rubber; its evaporation is negligible and it can be recovered at the end of the cold season and used again. If alcohol that is lost by evaporation must be replaced four or five times in a season, glycerine at four times the price is less expensive even for one season. Glycerine solutions of higher specific gravity than 1.144 are not recommended for use in cars having thermosiphon circulation, because of their high viscosity at low temperatures.

Ethylene glycol is made indirectly from petroleum or ethyl alcohol and sold in the winter of 1925 and 1926 at about the same price as glycerine. It gives more protection against freezing than either glycerine or denatured alcohol solutions of the same volume-per cent, is practically non-volatile, is no more corrosive than water,

and is only slightly more viscous at low temperatures than denatured-alcohol solutions of equal concentrations.

In testing solutions for determination of their freezing-points, care must be taken to avoid the phenomenon of undercooling, that is, the tendency to resist freezing under some conditions at temperatures considerably below the maximum temperature at which crystals can begin to form. Apparatus used at the Bureau of Standards for making such determinations is illustrated and described. The present procedure and a proposed new method for testing the corrosive action of anti-freeze liquids are also described.—[Printed in the July, 1926, issue of THE JOURNAL.]

THE DISCUSSION

G. A. ROUND¹¹:—Last winter our attention was called to the objectionable leakage in a number of cars which followed a change from the use of water in the cooling systems to an ethylene-glycol anti-freeze solution; in fact, one manufacturer who is marketing a product of this character felt obliged to advertise that the solution should not be used in certain makes of car because of this trouble. This is unfortunate, to say the least, because the high boiling-point of the glycol solution is a very desirable property that is not possessed by the alcohol-water solution.

To develop this matter we made rough tests with some new samples of rubber gaskets and hose from the cars in question to determine the effect on them of immersion in the glycol solution. The results of continuous immersion at a temperature of 194 deg. fahr. are shown in Table 1. As the first column indicates, both gaskets and hose absorbed a considerable quantity of either cooling solution, but more water than glycol was absorbed. This absorption causes a swelling action. If glycol solution is put into a system in which water has been used, it quickly draws some of the water out of the gasket or hose, with the result that the gasket or hose shrinks or collapses to a certain extent. This is indicated by the data in the second column of the table and is the reason for the leakage that occurs.

TABLE 1—EFFECTS OF WATER AND GLYCOL ON RUBBER GASKETS AND HOSE

	Increase in Weight after Immersion for 24 Hr. with Solutions Reversed, 30 Days, Per Cent	Increase in Tensile- Strength, Per Cent	Thickness Regained Under Com- pression, Per Cent
Gaskets			
New			82.6
Water Immersed	55.0	27.0	67.9
35-Per Cent Gly- col Immersed	33.4	37.0	77.5
Hose			
Water Immersed	153.0	115.0	...
35-Per Cent Gly- col Immersed	124.0	135.0	...

Some have thought that the glycol solution has an injurious effect on rubber. However, the third column of the table shows that it affects the tensile strength of rubber to a less extent than water, while the last column shows the same thing in a different way. To obtain these data the gaskets were subjected to a load

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¹¹ M.S.A.E.—Assistant chief of the engineering division, automotive department, Vacuum Oil Co., New York City.

of approximately 10 lb. along $\frac{1}{2}$ in. of their circumference and the degree of compression measured. The amount of thickness regained when the load was removed is indicated in percentage by the figures in the last column. From these it is apparent that the glycol solution caused less swelling of the gaskets than did water.

In view of these facts, I would suggest that anyone who is considering the use of glycol should renew the hose connections before putting in the anti-freeze solution and that when the danger of cold weather is past and straight water is used again, the same thing be done. In that way perfect satisfaction will be obtained; otherwise leakage troubles are to be expected.

H. S. COITH¹²:—It is interesting to note that glycerine, which has the highest viscosity with the exception of the honey solution, and which one would suppose might give trouble from poor circulation under low-temperature operating conditions, apparently does not do so, as is evident from the fact that a glycerine solution was used in the Norge in its recent flight over the North Pole.

T. S. SLIGH, JR.:—The main trouble, I believe, with materials of high viscosity occurs in the starting period, before the solution has warmed up. The Norge probably did not encounter very much of that.

OBJECTIONS TO THE USE OF OILS

P. M. HELDT:—I should like to hear something about the use of kerosene as a cooling fluid.

H. K. CUMMINGS:—I have no information in particular regarding it other than that its lower cooling-capacity per unit volume is possibly a disadvantage, but in spite of that kerosene is fairly satisfactory in cold weather provided the shutters on the radiator are left open. It permits normal engine-operation under low temperature conditions and the only criticism of its use is that when warm spells come, especially if the circulation is not mechanical, the engine may be allowed to overheat. Some who have used kerosene report very satisfactory results with it.

MR. HELDT:—What effect does it have on the rubber hose?

MR. CUMMINGS:—If the liquid is allowed to overheat, the hot kerosene attacks the rubber somewhat rapidly. The rubber retains its qualities longer if the liquid does not become overheated, but in all cases the effect is undesirable. Mr. Round has shown, on the contrary, that in the case of glycol a differential effect occurs between the quantities of water and of glycol absorbed. The Procter & Gamble investigators have shown exactly the same results for the glycerine solution. Those cases are distinctly different from the action of oil on rubber.

M. C. HORINE:—Are any data available on the use of transformer oil for cooling?

MR. ROUND:—About 10 years ago we conducted some tests to determine the advisability of marketing a petroleum product for use in engine cooling-systems. The oil we tried was of light body and very low pour-test and was in general use as a fluid for hydraulic mechanisms, recoil checking devices and so on. Insofar as use in cooling systems is concerned, it would give the same results as a transformer oil.

In service the results obtained were first, a pronounced increase in the tendency of the engine to detonate; second, leakage; third, a disagreeable oily odor; and fourth, rapid deterioration of the hose connections. With

some engines the knocking, even at moderate acceleration rates, was very severe; with others it was not really objectionable but nevertheless sufficient to cause user complaints, particularly in those days when anti-knock fuels were unknown. This and the other objections mentioned led us to drop the matter.

In individual cases, where leakage is absolutely prevented and the odor of the liquid cannot reach the passengers, an oil of this type can be used satisfactorily in connection with an anti-knock fuel but we believe that the objections to oil for cooling, which include a slight fire risk, far outweigh any advantages it may have, particularly in comparison with the glycol solution.

R. E. PLIMPTON¹³:—The table for using 50-per cent glycerine showed a sudden increase from 4 parts of glycerine by volume to 1 part of water for —20 deg. Fahr. to 9 parts of glycerine to 1 part of water for —30 deg. Is that actually required? It seems to be out of line with the preceding figures.

Four or five renewals of alcohol during a winter season for a car operated 100 miles a week were mentioned by Mr. Cummings. Were the renewals checked with a hydrometer or was the alcohol renewed more or less by guess? Would that ratio hold if the same vehicle were operated at 100 miles a day?

MR. CUMMINGS:—The total quantity of replacement alcohol required is merely a rough estimate; we assumed that alcohol is added every day or so to keep the proportion constant. Greater mileage of operation would have very little effect; the effect depends almost entirely upon whether the engine has much or little heavy duty.

As regards the glycerine-water proportion, the 3 to 1 was for —10 deg. Fahr., the 4 to 1 for —20 deg., and the 9 to 1 for —30 deg. The actual initial freezing-points corresponding to these are —4, —10 and —18 deg. Fahr. The allowance increases with concentration, because the more concentrated solutions contain less water to freeze and the volume of ice crystals in the system will be less.

GLYCERINE DOES NOT FORM A DEPOSIT

CHARLES L. SHEPPY¹⁴:—The statement that glycerine solutions form a deposit in the radiator was brought to my attention by a radiator manufacturer, and to test this we built a top and bottom tank on a small section of a radiator core, introduced a glycerine solution and kept it boiling for about 500 hr. When we cut open the radiator section we found a deposit but our chemists were unable to say that it was from the glycerine. I believe that the material deposited was silicate that came from the water and was not anything precipitated from the glycerine. Has anyone found that glycerine does form a deposit inside the system? We did not try to solder the section after it was cut open.

MR. CUMMINGS:—I think the tendency of glycerine is exactly the opposite. Glycerine has more or less of a rust or scale-removing property and possibly in some instances may by that action open-up or reveal small leaks that had been plugged previously by rust. It has no tendency, so far as I know, to produce an increased deposit. Some deposit will, of course, result from evaporating water throughout the season, and if the water is hard the normal scale-forming action will occur.

CHAIRMAN J. F. WINCHESTER¹⁵:—To renew the hose of the radiator connection may be necessary, as Mr. Round indicated. In experiments that were conducted on a fleet of trucks with which I am intimately acquainted we found that even though many data on the necessity of keeping joints tight were placed in the hands of the

¹² Chemical division, Procter & Gamble Co., Ivorydale, Ohio.

¹³ M.S.A.E.—Associate editor, *Bus Transportation*, New York City.

¹⁴ M.S.A.E.—Chief engineer, Pierce-Arrow Motor Car Co., Buffalo.

¹⁵ M.S.A.E.—Supervisor of motor equipment, Standard Oil Co. of New Jersey, Baltimore.

junior engineer who was conducting the experiments, one of the first things he overlooked was the tightening of the rubber connections after these solutions were put in. The result was that considerable of the material was lost in the early part of the experiments in certain cases. After the connections were tightened we did not have to tighten them the second time and had very little loss. The cooling-systems of the trucks were drained this year after the trucks had run about 5000 miles and no ill effects on the cooling-systems were noticed. I have heard nothing from the repair men working on these radiators regarding the deposits mentioned by Mr. Sheppy.

The relative cost has considerable to do, I think, with the practical use of the different materials. We put alcohol, glycerine and ethylene glycol solutions in a group of about six trucks each. The respective costs of these three materials last year at wholesale prices were practically 51 cents, \$2 and \$3 per gal. The difference is considerable and glycerine or ethylene glycol must have considerable advantage to make them pay against alcohol. They have certain distinct advantages as regards the mechanism of the cooling-system and if the hose connections are kept tight a solution is reasonably certain to last throughout the winter provided the proper mixture is used. Their use is not so important in extremely cold climates as in some of the Southern States where the nights are very cool and mid-day is very warm. Under such conditions a man may arrive home at night after having boiled most of the alcohol out of the solution, and if he does not check up with a hydrometer and refill the radiator, he may find a cracked cylinder in the morning. This is one of the difficulties overcome by these two other more-expensive solutions. The relatively high boiling-point is one of the distinct advantages we found in this type of material. In cold climates where zero temperatures occur from time to time, I am inclined to believe that, in the long run, alcohol would be the cheaper product for the general operator to use, provided the solution is watched closely.

I have yet to find a man associated with the petroleum industry who will recommend kerosene or any other oil for cooling any type of engine unless the engine is especially designed for the purpose. We have done considerable experimental work with oils and they never have proved satisfactory.

I doubt if changing the hose connections is necessary, particularly if the information that Mr. Round gave regarding the effect these materials have on the connections is correct.

MR. ROUND:—Tightening the connections will help considerably but these connections are seldom replaced on most cars and while the outside looks all right the inside is often defective. To recommend to the layman that he renew the hose connections periodically is not a bad idea. This probably is not necessary in the case of carefully supervised fleets of trucks. The trouble that was brought to our attention occurred in the case of individual owners. The firm that was marketing the anti-freeze product had so much trouble that it advertised that the product was not suitable for those particular vehicles, but actually all that was needed was a set of new gaskets before the solution was put into the cooling system.

MR. PLIMPTON:—Can Mr. Winchester tell us the cost per mile for the three solutions used in the groups of trucks he mentioned?

CHAIRMAN WINCHESTER:—Each group was operated

approximately 5000 miles. The cost per season for alcohol was approximately \$2.95 per vehicle, for glycerine it ran approximately twice that and for glycol it was about 2½ times the cost for alcohol. That was in and around New York City. The ultimate cost cannot be determined at this time, because the solutions were drained from the engines and will be used again next season.

EFFECT OF VISCOSITY IN THERMOSIPHON SYSTEMS

E. P. WARNER¹⁶:—All of the problems with anti-freeze solutions seem to become especially complex when dealing with thermosiphon circulation. The low boiling-point of alcohol, the low heat-capacity of kerosene and the high viscosity at low temperature of the glycerine and ethylene glycol are especially troublesome then. We cannot afford to have any increase in resistance of the flow in the circulation that can be avoided. We can circulate any liquid if we can use the right pump. Has Mr. Cummings any definite figures on the effect of the viscosity of which he has spoken on the rate of circulation and on the temperature variation in such a system; that is, the difference between the total temperature-range in the thermosiphon system in the water-and-alcohol and the water-and-glycerine solutions?

MR. CUMMINGS:—We have no experimental figures along that line. We were in doubt whether low-temperature viscosity-measurements would be desirable or necessary in view of the uncertainty where the critical point might come, but as between any two materials, other things being equal, the less viscous material must obviously have a certain advantage over the more viscous one.

MR. COITH:—The answer to this question may be found perhaps in the fact that a great many persons have thermosiphon cars operating successfully with the more viscous solutions in such districts as the Minneapolis region where the temperatures are rather extreme.

A MEMBER:—What is the objection to using a radiator liquid in connection with glycerine? On my own car I have a pump that is very hard to keep tight. Last autumn I put glycerine and a can of radiator liquid in the radiator and did not lose a tablespoonful of the solution all winter and did not tighten the hose connections.

MR. SHEPPY:—I found that the glycerine solution sometimes creeps out through the cylinder-head or cylinder casting that has been perfectly tight with water, but it does not leak out in any large quantity; frequently a little bead appears on the surface of the metal, then dries up and the leak stops. Our experience has been that, while the cost of glycerine is much higher than that of alcohol, the former is much more satisfactory as an anti-freeze material in that the solution will last through the whole season if the leaks are not excessive. I think, with temperatures such as we have around Buffalo, glycerine is more economical than alcohol.

SIMPLE HYDROMETERS NEEDED FOR SOLUTIONS

CHAIRMAN WINCHESTER:—The glycerine and glycol manufacturers did not supply hydrometers or tell where they could be obtained so that car users could test the gravity of the mixture when it was put in the radiator. I am inclined to believe that as a result both of these products had a poor reputation last winter. The furnishing of hydrometers with both materials would, in my opinion, assist in bringing about their general use with more satisfactory results.

MR. HORINE:—The usual garage is equipped only with a battery hydrometer, which does not read in the alcohol range. I have tried in vain to obtain a hydrometer at an ordinary garage with which I could read alcohol gravity.

¹⁶ M.S.A.E.—Professor of aeronautical engineering, Massachusetts Institute of Technology, Cambridge, Mass

I understand that the battery hydrometer, however, will give a reading on glycerine mixtures.

MR. SHEPPY:—We never had any difficulty in obtaining hydrometers that had been made up with charts and gave the desired figures. All that is necessary is to refer to the temperature and hydrometer reading on the chart and it will show at what temperature the solution will freeze. Similar charts for glycerine solutions are available.

CHAIRMAN WINCHESTER:—The point is that the hydrometer should be so simple that the average service-station man can use it readily and quickly. Engineers become so used to reading charts and so intimately acquainted with figuring that we think nothing of it, but the average man who is given an instrument and a chart is not inclined to use them. Moreover, an opportunity exists for considerable deceit in this matter, particularly where these products must be dispensed through service stations. The simpler the hydrometer is made the better. Instruments called freezometers, which are nothing but inverted hydrometers, have been on the market for years but the difficulty with both the glycerine and glycol materials has been that no instrument having a scale that would make the reading of the gravity of these solutions easy has been distributed generally.

MR. COITH:—Such hydrometers were put out last year for these other anti-freeze materials but they were new and did not receive very wide distribution.

Speaking of servicing with an anti-freeze, such as a glycerine or glycol solution, which, when it seeps out, remains to show where the leak is, minimizing the appearance of leaks, is simple. If before draining the water from the car about 1 pt. of oil is poured into the radiator and allowed to ride the surface of the water as it recedes when the car is drained, and then as much of the oil is allowed to run out as will conveniently do so, apparently two things are accomplished: a film of oil is left on the inside of the cooling-system, and a small quantity of oil remains in the system. Then, when the anti-freeze solution is put in, the film seems to keep it from penetrating pinhole leaks and the oil has an action similar to that which occurs in the flotation process of ore extraction; namely, it coagulates the rust particles in little flocculent groups that lodge in the small apertures and prevent leakage. As oil is a common material in the garage, this is a very simple and convenient treatment.

CHAIRMAN WINCHESTER:—Do you recommend kerosene or lubricating-oil?

MR. COITH:—A rather heavy lubricating-oil.

MR. CUMMINGS:—Mr. Coith's recommendation is practically the equivalent of that regarding the use of the X-liquid. The disadvantage attaching to the use of an excessive quantity of oil is that it may have a tendency to produce foaming.

F. C. BOOTH:—If the makers of glycerine and glycol want to make the testing of the gravity of the mixtures easy for the car-owner they have only to suggest that the owners go to a radio store or an automobile accessory store and purchase one of the cheap hydrometers that are sold for the purpose of reading the condition of radio batteries. The scale range is sufficient for the gravity of solutions of glycerine and glycol.

CHAIRMAN WINCHESTER:—I am inclined to believe that with some of these materials a conversion table on the hydrometer is necessary at least. If these companies furnished a table so that the usual hydrometer could be used, to have the conversion table on the slip would be necessary too.

MR. CUMMINGS:—With regard to the use of hydrometers to estimate the protection against freezing that is afforded by solutions more dense than water, I believe that the marketers of such solutions will find providing fleet operators and service stations with hydrometers of suitable range together with charts or conversion tables which give the freezing-point corresponding to the hydrometer reading at any temperature from 32 to 100 deg. fahr. advantageous. Mr. Winchester is right in pointing out that provision should be made for the temperature correction. However, frequent gravity-checks are far less important with glycerine or glycol solutions than with denatured-alcohol solutions.

The ordinary storage-battery tester contains a hydrometer graduated from 1.100 to 1.300 in steps of 0.005 or 0.010. The specific gravity of commercial ethylene glycol is about 1.115 and that of 60-per cent radiator glycerine is about 1.160, so any service station handling these products in bulk can satisfy a customer that he is getting undiluted material by using the battery tester. The concentrations of glycol required in the radiator have a specific gravity of 1.030 to 1.070 and are below the range of the battery tester, but it will serve for glycerine solutions of about 1.110 specific gravity, which give protection to 0 deg. fahr. or lower.

INFLUENCE OF TEMPERATURE, FUEL AND OIL ON CARBON DEPOSITION

BY S. P. MARLEY¹⁸, C. J. LIVINGSTONE¹⁹ AND W. A. GRUSE²⁰

ABSTRACT

HIGH operating-temperature, the use of the more volatile fuels and a lean air-fuel mixture and the use of lubricating-oils of relatively high volatility which contain little carbon-residue all tend to reduce the deposition of carbon in an internal-combustion engine, as indicated by the experimental study reported in this paper.

Believing that heat, fuel and oil are the most important factors influencing carbon formation and deposition, the experimenters adopted the method controlling closely the other conditions of operation of a specially designed single-cylinder test-engine and varying the operating temperature and the fuel and oil, allowing the carbon deposit to build up in the normal way during the test periods of 15 and 36-hr.

The test engine and control apparatus and the test procedure are described. Room temperature was held constant throughout each run, oil and cylinder-head temperatures were controlled to within 6 deg. fahr., the air-intake temperature was kept constant within 1 deg. fahr., the engine-speed was measured in revolutions per minute, and the rate of fuel intake was held

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¹⁹ M.S.A.E.—Industrial research fellow in petroleum technology, Mellon Institute of Industrial Research, Pittsburgh.

²⁰ Jun. S.A.E.—Industrial research fellow in petroleum technology, Mellon Institute of Industrial Research, Pittsburgh.

²⁰ M.S.A.E.—Director of petroleum investigations, Mellon Institute of Industrial Research, Pittsburgh.

constant at a constant throttle-setting, giving a uniform air-fuel ratio as determined by exhaust-gas analysis. As confirmation of the accuracy of control, it was observed that the power output was constant within an average of 1 per cent.

After conclusion of a run, the engine was taken down and the carbon deposits from the piston and from the cylinder-head were recovered separately and weighed. Seven different liquid fuels and six different lubricating-oils were used in the various runs.

From data obtained it seems that the carbon values are fairly constant until the head temperature rises somewhat above 400 deg. fahr., after which there is a drop in them as the heat is increased. Deposits formed at the lower temperatures are much more asphaltic, softer and less adherent than those formed at the higher temperatures. With evaporative or steam-cooling, the head temperature was as low as or lower than the lowest with water-cooling, and carbon deposition was almost at the same rate as with water-cooling at the same temperature.

No marked change in quantity of carbon is noted with different fuels through the series of commercial gasolines, but excessively high carbon-values were obtained with the heavy cleaners' naphtha and kerosene, due, it is believed, to poor carburetion and incomplete oxidation and to asphaltization of sprayed liquid. Benzol blend gave slightly more deposit than motor fuel, but the deposit was softer and more soot-like. Natural gas gave only 5 per cent less deposit than commercial gasoline, which is interpreted to mean that in a 12-to-1 mixture a good average grade of gasoline plays a very small part in the deposition of carbon.

It runs simulating ordinary cool-weather operation of automobiles, with a 10-to-1 ratio of air and ordinary automobile gasoline, lubricating-oils distilled from Pennsylvania and Mid-Continent crudes gave considerably

higher carbon-deposits than oils derived from Gulf Coastal crudes. The different oils suffered dilution in the crankcase to the same extent with the same fuel and operating conditions.

Under conditions simulating summer operation, with a mixture-ratio of 12 to 1, the carbon deposit with Gulf Coastal oil was only half of that with Pennsylvania oil, while that from Mid-Continent oil was midway between. Extraction figures from the Gulf oils show that they contain less oily matter than the less-volatile oils. Carbon from them was, in general, dry, powdery and friable, while that from Pennsylvania oils was very hard and adherent over the hotter areas and sticky and asphaltic over the cooler areas of the combustion-chamber. Popular belief that there is a connection between so-called heat-resisting properties of an oil and its desirability as a lubricant is probably erroneous; the oil that will leave the least residue upon evaporation from the metal surfaces will give the least trouble from carbon deposition.

Suggestions offered for avoidance of carbon trouble are that (a) oil consumption be kept at the minimum consistent with a fair margin of safety, (b) excessive and irregular cooling be avoided, (c) the fuel-air mixture be kept on the lean side of smooth operation, and (d) the oil that is the more volatile among those of the same viscosity probably will be the more satisfactory.—[Printed in the June, 1926, issue of THE JOURNAL.]

THE DISCUSSION

G. A. ROUND²¹:—The authors of this paper have done some very interesting work and we agree thoroughly with some of their conclusions, but they have not mentioned some factors that in my experience have a far greater effect on carbon formation in an engine than do some of the factors that have been discussed in this paper. From our experience we are inclined to feel that the effectiveness with which the piston-rings prevent oil

²¹ M.S.A.E.—Assistant chief of the engineering division, automotive department, Vacuum Oil Co., New York City.

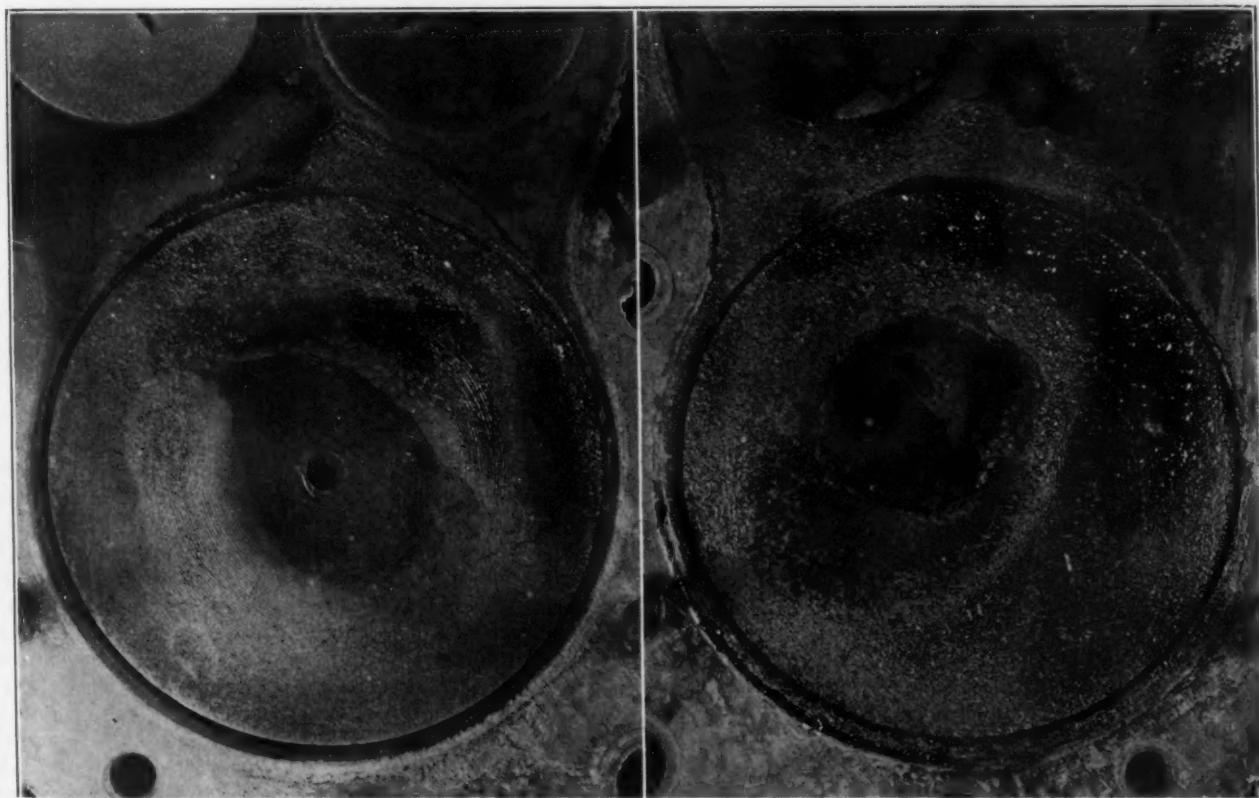


FIG. 2—THE INFLUENCE OF RING EFFICIENCY ON CARBON DEPOSITS
The Wide Difference in the Amount and Character of the Deposit on Two Pistons at the End of 16 Hr. Running on an Oil of 0.30 Per Cent Carbon Residue Value Is Clearly Indicated

passage into the combustion-chamber is probably the largest single factor controlling the formation of carbon deposits. The two photographs that are reproduced in Fig. 2, which together with the others used to illustrate this discussion were taken in connection with a test conducted on a four-cylinder motor-truck engine, illustrate this point. These are of two pistons after a 16-hr. run on a heavy medium-bodied oil with a carbon-residue value of approximately 0.3 per cent. As the photographs indicate, the piston at the left is practically free from carbon, whereas the surface of that at the right is partially covered with a heavy deposit that is surrounded by more or less oxidized oil. Judged on the basis of the left piston, the performance of the oil was good but the average person would be inclined to feel that the oil was carbonizing excessively if he were to see the right

somewhere near its normal capacity. Under heavy load conditions oils that might be expected to give a heavy deposit if their carbon-residue value alone was considered, will usually leave but little deposit unless the rings are in poor shape. Doubtless the factors of temperature and mixture-ratio play a part in producing these results, but from a practical operating standpoint the quantity of deposit will usually be found to vary inversely with the loading.

Concerning the effect of the duration of a test run on the carbon formations, in our opinion the 36-hr. period used in the authors' test work was more than sufficient to establish an equilibrium condition, when the fact that the engine was run under full load is considered. From our experience the conditions that will be present after practically any period of running either will be shown

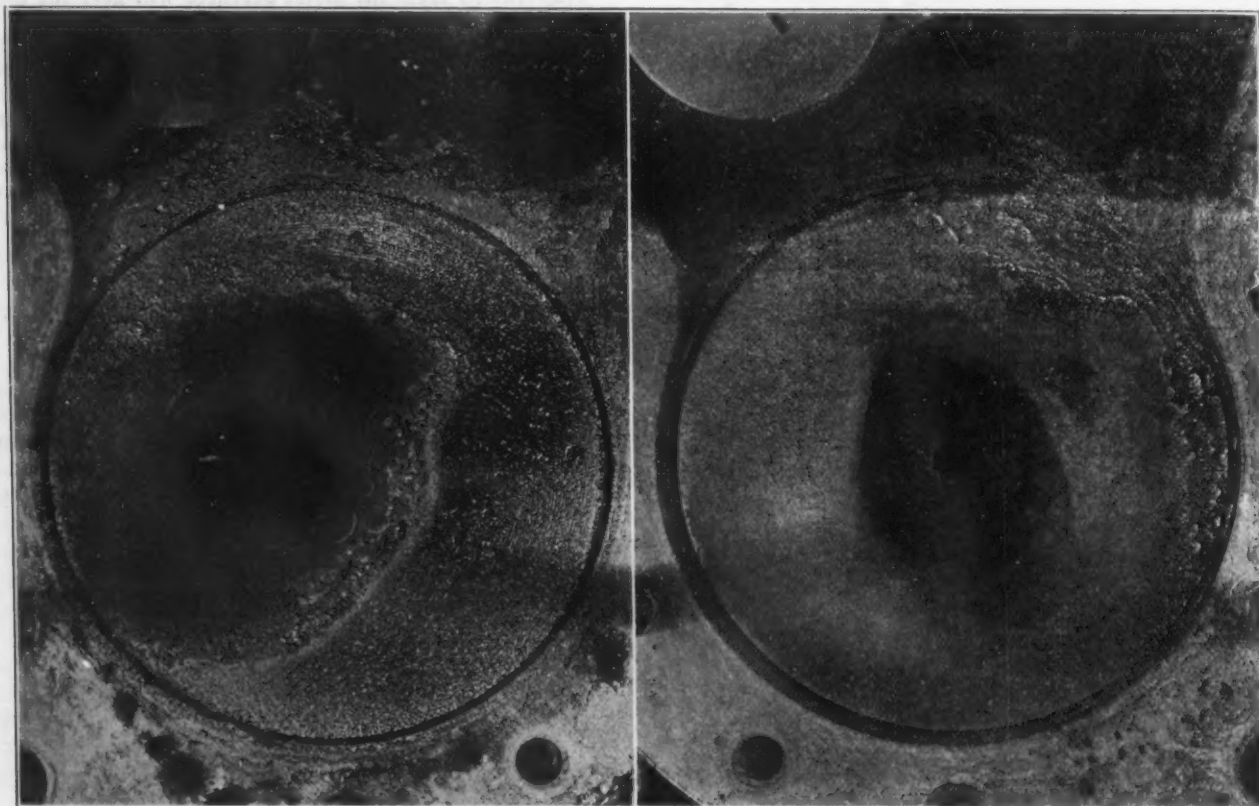


FIG. 3—FALLACY OF BASING PREDICTIONS OF THE AMOUNT AND CHARACTER OF THE DEPOSITS TO BE EXPECTED ON THE CARBON-RESIDUE VALUE

The Deposits on the Left Piston Resulted from 32-Hr. Use of an Oil of 0.09-Per Cent Residue Value, While Those on the Right Formed after the Same Period on an Oil of 0.30-Per Cent Residue Value

piston alone. As far as could be determined, the only thing affecting the rate of carbon formation in this case was the ring equipment.

Fig. 3 shows how little importance can be attached to the carbon-residue value of the oil in predicting the quantity of carbon formed from it. The deposits on the left piston were formed from an oil having a carbon-residue value of 0.09 per cent, while those on the right piston were from an oil having a Conradson carbon-value of 0.30 per cent, the same oil as mentioned in connection with the photograph shown in Fig. 2. Here again the factor of ring effectiveness is the controlling one.

The next most important factor affecting the quantity of deposit is the load that the engine is carrying. Experience shows that an engine which is running under a relatively light load or in intermittent service will accumulate carbon much more rapidly, even when a light clean-burning oil is used, than one which is operating at

or can be predicted from the character of the deposits that are present after a run of 16-hr. length.

Referring to Fig. 4, the photograph on the left shows the conditions on one piston after 16 hr. of running, while the one on the right shows how little change has taken place with another 16 hr. of operation. These show the conditions with a low carbon-residue-value oil and effective rings. Fig. 5 shows the conditions with less efficient rings and an oil of high-carbon value. Little difference between the deposits can be noticed, but over a long period of time under actual service conditions we may expect that the area of the piston, which in these two illustrations is covered with more or less oxidized oil, will eventually be coated with soft carbon in which any foreign material drawn in with the intake air will be collected.

We use the photographic method of recording carbon deposits and collect and analyze the accumulations as well.

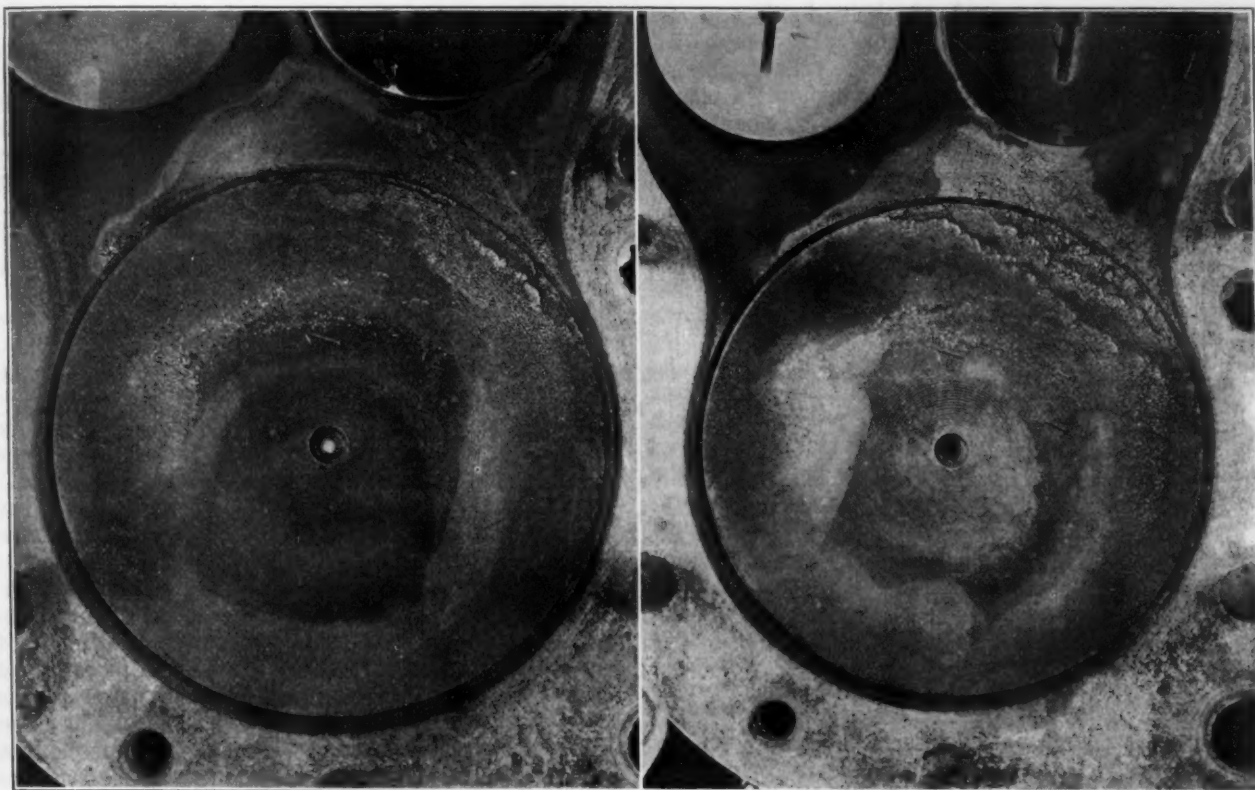


FIG. 4—THE EFFECT OF TEST DURATION ON CARBON ACCUMULATIONS WHERE THE RINGS ARE EFFECTIVE
Deposits on Left Piston Are after 16 Hr., on Right after 32 Hr.

Weighing the carbon accumulations alone does not tell the whole story because when a portion of the piston is coated with more or less gummy oil, as in Fig. 5, this

section is practically certain eventually to become coated with carbon. In a few cases we have not only photographed the deposits, but have made plaster casts of

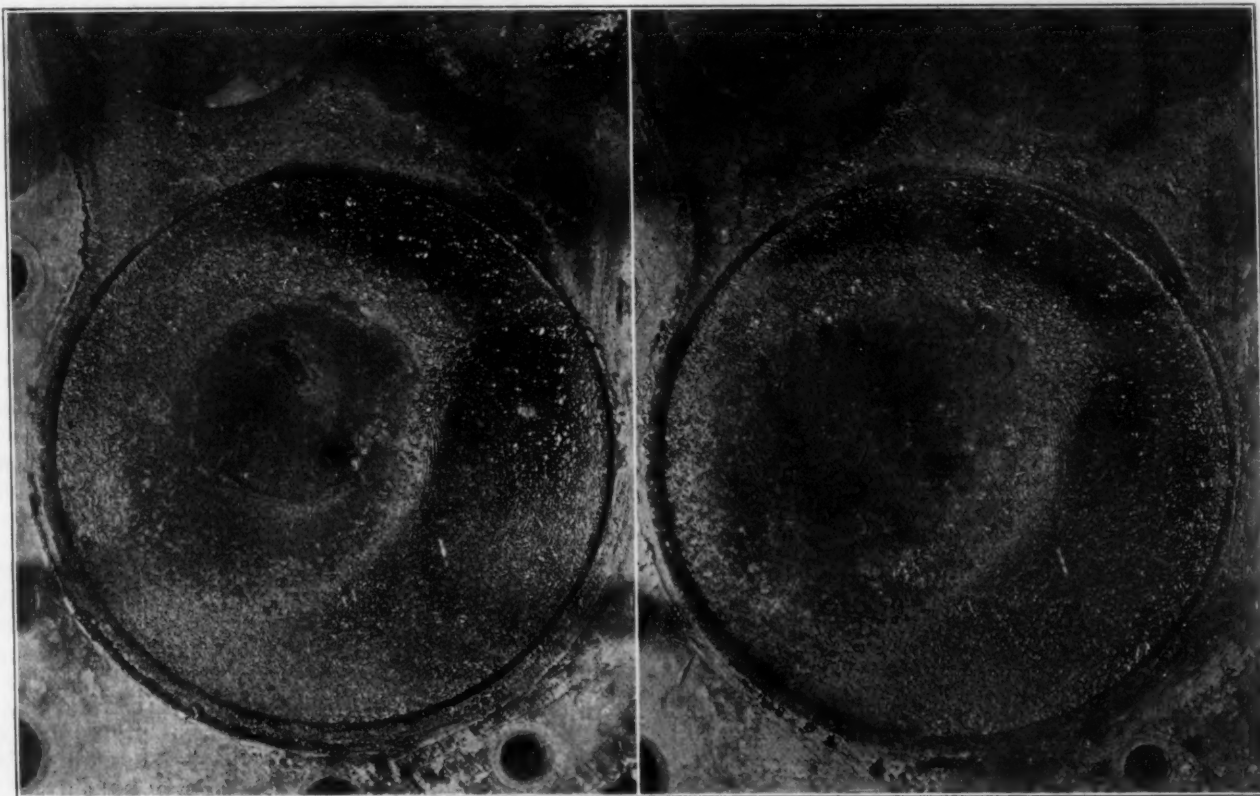


FIG. 5—THE EFFECT OF TEST DURATION WHERE THE RINGS ARE NOT EFFECTIVE
Left Photograph Was Taken after 16-Hr. Run; Right Photograph after 32 Hr. Over a Long Period the Oil-Covered Surfaces of the Piston-Heads Will Become Coated with Carbon

them as a permanent record of their depth and distribution, something that the ordinary photograph does not permit because of lack of perspective. To do this the piston is first coated with a parting compound; a plaster of paris impression is next obtained, giving a negative of the deposits. By coating this negative with the parting compound, which any company furnishing dental plaster will provide, a positive cast of the deposits can be made.

W. A. GRUSE:—I should like to agree with Mr. Round in much of what he said. That photographs do not show much is true. We made photographs of every one of our runs but did not present them because they do not show anything. Mr. Round's illustration is correct as regards the influence of the rings, but all of our results are given with those conditions constant. Every factor we could think of was controlled. All we can say with regard to the rings is that occasional variation occurred in the checks we made with the average position of the rings practically the same, so we feel that our work presents a true picture of what happens when all the factors are held constant.

NATURE OF DEPOSITS AFFECTS DETONATION

A MEMBER:—I do not see that to know the actual weight of carbon in the engine is of particular interest. Most car-owners are worried about carbon deposits only insofar as they affect detonation. In our own work along this line we have not gone far enough to obtain proof, but I suspect that different carbon formations may occur which, for the same weight, will have considerably different effects on detonation; that is, a very soft spongy carbon well distributed over the piston-head might not have the same effect as a flaky dry carbon in which the edges of the flakes become incandescent with the heat. We find that measuring the effect of carbon in the engine simply by studying the detonation is really feasible. I do not see wherein the other variables are of much more than academic interest.

S. P. MARLEY:—I should like to say, with reference to the character of the carbons we have found in the engines, that the carbon from the Coastal lubricants is, in general, soft and the deposit over the hotter areas of the pistons and combustion-chambers is rather soft and friable and easily removed; it could be blown out rather easily by the exhaust. We find that deposit from oil from the paraffin base is extremely hard and to loosen it from the engine is a real task. This harder paraffin deposit would tend to increase the heat insulation considerably.

MR. ROUND:—There again are some variables that have not been taken into consideration, I think. An arbitrary statement that the nature of the crude affects the character of the carbon deposits is perhaps somewhat misleading. Our experience has led us to believe that not only the character of the crude but the method of refining and the nature of the product of the refining process are factors. I have seen oils made from the upper-district Pennsylvania crude which would leave the lightest carbon-deposits anyone would wish to see in an engine. I have also seen the same kind of deposits formed from naphthene-base crudes. All the various qualities of oil between the two are obtained simply by changing the stocks and their treatment; therefore I would not agree with a general statement that any one type of crude would produce any one kind of deposit under a certain condition.

C. J. LIVINGSTONE: Mr. Round's criticisms of our work boil down to (a) an implication that we did not consider certain variables which he has found to be important and

(b) a suggestion that he does not believe we should make an arbitrary statement that the nature of the crude affects the character of the carbon deposit.

Certain variables of engine operation will, Mr. Round feels, affect results more than will the kind of oil used. To this we agree, but we must insist that these variables were eliminated by control. The three that Mr. Round mentions are (a) piston-rings, (b) time and (c) load. No change in piston-rings was made during a series of runs, and the same type of ring was used throughout the work. Our runs were made by the clock, and the number of revolutions per hour and per run was kept constant. Our minimum time, 15 hr., is about the same as that mentioned by Mr. Round as satisfactory, 16 hr., and our other interval was 36 hr. Fifteen-hour runs were compared only with 15-hr. runs and 36-hr. runs only among themselves. Time of operation is significant only if oil consumption is regulated, and this we did. We have found that an excessive quantity of oil admitted to the combustion-chamber often serves to keep down the quantity of carbon deposited per unit of oil burned. This is perhaps because carbon is formed at the surface of a thick film of oil which prevents it from adhering to the metal surfaces. It is then washed or blown out of the combustion-chamber. This method of minimizing carbon deposit is not to be recommended. Our paper is perfectly clear in the statement describing the extent to which the load was controlled. Given a constant amount of external cooling, variations in load are effective through their influence on cylinder-head temperature. Not only was our load control adequate, but the head temperature was held as constant as possible.

Mr. Round is entirely correct in his thought that variations in rings, time or load may sometimes affect deposit more than variations in the type of oil used. This should be obvious to anyone who has had experience in engine work. We did our best to eliminate the former variables and to examine the influence of changes in oil with such care that our tests would meet the ordinary requirement of duplication, a condition that is somewhat rare in engine work. In this we believe we have succeeded, and we feel further that the differences in oils brought out in our work express a fundamental tendency which may be masked or neutralized by variables of operation, but which will always be active.

Mr. Round says that an arbitrary statement that the nature of the crude affects the character of the deposits is likely to be misleading, because he believes that the method of refining and the nature of the product refined are also factors in the character of the deposit produced. This statement may be entirely correct, but we believe that our argument will hold for ordinary typical oils refined in the customary ways. We are not prepared to discuss the influence of drastic filtering or other processes that are ordinarily applied to laxative mineral oils but not to engine oils. To mention that the oil which gave the most carbon in all tests was that which sold at the highest price and should therefore have been the one most likely to be most adequately refined may be of interest.

Taking plaster casts of the piston deposit is very interesting but does not impress us as very practical. To apply the same procedure to the cylinder-head does not seem feasible, and we are at a loss to understand how he evaluates the weight of the deposit or its thickness. Since Mr. Round mentions the use of a multi-cylinder engine we are prompted to wonder if he did not encounter the variations from cylinder to cylinder mentioned by Orelup and Lee, and encountered by many other investigators.

ROBERT F. KOHR²²:—With reference to rich and lean mixtures, I have worked in a laboratory for some years and, to my knowledge, a 12-to-1 mixture is barely lean enough for maximum power. This ratio is not by any means the limit of leanness as regards smooth engine-operation. I think that in speaking of lean mixtures that some really lean mixtures were not included is to be regretted. Possibly some engines, perhaps the one with which these experiments were conducted, are incapable of smooth operation on leaner than 12-to-1 mixtures, but that is not usually the case with one-cylinder engines. In general the mixture-distribution problems we usually have with multi-cylinder engines do not affect one-cylinder engines, which can be run on somewhat lean mixtures. Why was the work not carried on with somewhat leaner mixtures than 12 to 1?

MR. MARLEY:—It may be well to state that the work done by the Bureau of Mines at Pittsburgh shows that the average automobile on the road operates on a mixture-ratio of 7 or 9 to 1. If that is the average air-fuel ratio in operation, it seems to me that our work was done with the somewhat lean mixtures; if I am wrong I want to be corrected. Apparently in the discussion I confused a 7 or 9-to-1 ratio with 7 or 9 per cent of carbon dioxide in the exhaust-gases, corresponding to an 11 or 12-to-1 ratio, the actual conditions we employed.

MR. KOHR:—Considerable laboratory work done at the Bureau of Standards during the time I was there showed that maximum-power mixtures ran usually between 12 and 13 to 1. Adjusting the carbureter will give about that mixture under normal conditions when not choked. If fuel economy is the aim, leaner mixtures than that will be used. Anyone who is running on mixtures of from 7 to 9 to 1 will change spark-plugs frequently, I believe. Reference to a ratio of 12 to 1 as a lean mixture came to me as a shock because of previous experience.

MR. GRUSE:—We did not indicate how an engine will operate; we simply selected the 12 to 1 ratio as representing approximately passenger-car driving conditions as we understood them from the experience we had. Not long ago we observed a car operating on a mixture of 14 to 1, but that is not the average.

CHAIRMAN H. C. MOUGEY²³:—Several years ago a long article by A. C. Fieldner, of the Bureau of Mines, Pittsburgh Experiment Station, was published in *Industrial and Engineering Chemistry*. The data given therein of cars on the road certainly did not indicate that the users cared anything about the cost of gasoline.

LOW CARBON-VALUES FROM DIFFERENT CRUDES

MR. GRUSE:—Referring to Mr. Round's remarks, I think we should not lay too much emphasis on the source of lubricating-oil at present. Our own data will show that an oil of proper volatility-range, even though made from another crude than the one that gave the lowest values in our tests also gave low values. I refer to oil No. 5, which was a distilled oil and which gave very satisfactory carbon value even though it was from the so-called paraffin or semi-paraffin base; it had a low boiling-range.

A MEMBER:—Some confusion exists, I think, in certain minds about two important factors in oils and engines that tend to increase the carbon deposits. One is

the laboratory method of the American Society for Testing Materials for measuring carbon residue; the other is the quantity of oil that works up into the combustion-chamber. Mr. Round has spoken about the types and fit of piston-rings. Proper piston-ring fit is only one of many ways by which the quantity of oil that reaches the combustion-chamber is controlled. We all know that high oil-pressure and tight or loose bearings will affect it.

Viscosity of the oil is one of the major factors that the oil man can control to regulate the quantity of oil that reaches the combustion-chamber. If a comparison is being made with two oils that have considerably different carbon-residue values and also very different viscosities, the resulting quantities of carbon in the cylinder may be the same, or may be very different from what would be expected. The Pennsylvania paraffin-base oils or the Mid-Continent or even Gulf Coast oils, have very low viscosity, or we will say, if dealing with distillates, they do not show much difference in carbon residues by the American Society for Testing Materials test-methods or even in the engines, but if a fairly high viscosity in the paraffin-base oils is desired they must be loaded with cylinder-oil stocks, the best of which, as we all know, are heavily loaded with carbon. Therefore, if we want to make a true comparison of the difference between oils from different crudes, we should consider the high-viscosity oils that can be obtained without the addition of cylinder stock only in the Gulf Coast type of oils. In other words, if an extra-heavy type of oil is used, the oils from the Pennsylvania and Gulf fields will show considerable difference in the carbon residue while, if one is comparing two oils of low viscosity, very little difference might be observed in oils from the two bases. A distinct difference is apparent in the comparisons if one uses two oils of different viscosities and then tries to show the carbon deposit in an engine as related to the carbon-residue value by the test-methods mentioned.

MR. MARLEY:—In reference to the comments of the last speaker on oil consumption and its control, I should like to say that the method described by Coleman and Fisher²⁴ appeals to me as a very satisfactory solution of the problem mentioned. They eliminate the splash to the piston entirely and supply a definite quantity of fresh oil by a pressure system with glands opening onto the cylinder-wall. The quantity of oil delivered to the cylinder-wall per revolution of the engine can thus be controlled very closely and definite information on the influence of variations in oil supply can be obtained.

CHAIRMAN MOUGEY:—How did the viscosity of the oils used in the tests compare?

MR. MARLEY:—We had two series of oils, one of matched viscosity of 350 Saybolt sec. and the second series of matched viscosity of 300 sec. We realize fully that if we use oils of different viscosities in attempting to establish our carbon values the result would not mean anything. We start with matched-viscosity oils, thus eliminating the viscosity effect on consumption. We start with as nearly a uniform product as possible, so far as viscosity is concerned.

A MEMBER:—I did not intend my remarks as criticism of the investigation. I saw at once that the viscosities were matched. I wished to call attention to the opinions of some men who perhaps had overlooked the matching of viscosities.

CHAIRMAN MOUGEY:—These viscosities were checked at 100 deg. Fahr., I believe.

MR. MARLEY:—At 100 and at 210 deg. Fahr.

CHAIRMAN MOUGEY:—How do they match?

MR. MARLEY:—They compared very favorably at 210

²² M.S.A.E.—Aeronautical engineer, bureau of aeronautics, Navy Department, City of Washington.

²³ M.S.A.E.—Chief chemist, General Motors Corporation Research Laboratories, Detroit.

²⁴ See THE JOURNAL, February, 1926, p. 201.

deg. The figures for the first series are 365, 356 and 358 sec. at a temperature of 100 deg. fahr. At 210 deg. they are 56, 54 and 49 sec.

A MEMBER:—The matching is shown by the oil-consumption figures, which were nearly the same in all instances.

MR. GRUSE:—I think we should emphasize the fact that the oils varied about as much as oils of the kind used will vary and that having the consumption check so closely indicates that the viscosity at 210 deg. is not very significant for consumption.

CHAIRMAN MOUGEY:—That is on oils under what viscosity at 210 deg.?

MR. MARLEY:—Under 56 sec.

CHAIRMAN MOUGEY:—Have you any data on oils of 60 or 70-sec. viscosity at 210 deg.?

MR. MARLEY:—No.

MR. ROUND:—I agree that the range of viscosity of the oils is not sufficient to develop the point fully; for instance, with oils from 200 to 800 or 900 sec. a much better indication would have been obtained.

MR. GROUSE:—We should like to use such a range but as we cannot readily match consumption on an oil of 300 and one of 500 sec., we used two sets of close viscosities. Our carbon values are corrected for consumption; that is, they are the grams of carbon deposit per liter of oil consumed.

CHARACTER MORE IMPORTANT THAN QUANTITY

EDWARD S. MARKS²⁷:—The photographs shown by Mr Round impressed me because the factor we have been considering is the character of the carbon deposits insofar as it affects detonation, since that is the reason we are particularly interested in carbon deposit. Our own observation and experience seem to show beyond doubt that detonation is affected more by the character of the deposit than by the quantity of carbon formed. In many cases much less detonation occurs when the carbon is in certain formations or locations in the combustion-chamber, although the quantity may be greater.

MR. LIVINGSTONE:—The point about evaluating carbon deposits in terms of detonation is a good one and we regret that we are not in a position to express our results in this way. On this question and the comment of Mr. Marks that the character of the deposit influences detonation to a great extent, our statements on the character of the deposits would seem to be of interest. The deposits from the more-volatile Coastal oils were powdery and sootlike, while the less-volatile oils gave dense, hard deposits that were more apt to flake and to cause preignition by incandescence. Even assuming that the denser deposits would have a higher heat conductivity, the difference in thickness of deposits and irregularity of surface were such that the probabilities seem all in favor of the Coastal deposits being the less troublesome.

T. S. SLIGH, JR.²⁸:—The oil apparently cracks to form carbon whenever it becomes hot enough and is kept in the hot place, and a carbon residue will not be formed if the oil is sufficiently volatile to leave the hot-spot before cracking. Therefore, naturally, an oil of high volatility will produce less carbon in a given hot place, as on a piston-head. This also suggests that the whole trouble may be avoided by slightly increasing the temperatures instead of lowering the oil volatilities.

One point on which I am not certain is whether, aside from the volatility of the oil, anything else affects the quantity of carbon deposited. An oil is spoken of as being full of carbon. I believe an oil contains no free carbon. What is done to an oil in the refining process, when starting with a given stock, to obtain a low carbon-residue oil?

A MEMBER:—I am not sure that Mr. Sligh intended that I should make a definite answer on something that he already knows all about. To answer his question properly would require a small book on refining, I think. When I spoke of an oil as being full of carbon I meant that when it is burned in the test it will show a large carbon-residue, as a cylinder stock will do, particularly if it has not been highly filtered. The more a cylinder stock is filtered and purified the less carbon residue it will give usually, although one cannot go below a certain minimum. I will admit, however, that to my surprise I have seen samples of cylinder stock from certain refining processes that are absolutely water-white and have practically no carbon residue. I understand, however, that these oils are impractical to produce on a commercial scale because only a very small percentage of the cylinder stock is of a character that can be treated by the process. This is simply another example of how far it is possible to go in the extremes of refining.

MOST DEPOSIT IS FROM UNBURNED FUEL

V. C. PARKER²⁹:—I wonder if we are not making a mountain out of a molehill. If one plots the percentage of Conradson residue in the average oil against the oil consumption in pounds per horsepower-hour, or any other power basis desired, he will find the figures insignificant. On the other hand, if the gasoline consumption with a mixture of 12 to 1 or richer is plotted against horsepower-hours, a slight excess of hydrocarbons will give incomplete combustion that will set free in the combustion-chamber a large quantity of finely divided carbon particles. If the mixture is enriched sufficiently, black smoke will issue from the exhaust-pipe of the engine. This exhaust is black only because it contains a great number of these particles. My experience has been that the carbon found inside the cylinder of an engine is much more likely to come from incomplete combustion of fuel than from incomplete combustion of oil, but I would not want anyone to think that the character of the oil does not affect the quantity of carbon deposited. Some kinds of oil contain substances which, when allowed to stew on top of the piston or in the cylinder-head for a sufficient time, become sticky or gummy. If the piston is covered with gummy deposits from the oil, these deposits will catch and hold the fine carbon particles set free during the incomplete combustion of a rich mixture and carbon deposits will build up very rapidly. Any measurement of carbon deposit that does not take into consideration the careful determination of the combustion characteristics of the partly consumed oil on the piston-head does not give all the facts.

MR. ROUND:—Mr. Sligh suggests raising the temperature. I believe Mr. Marks will tell him that when the temperature is raised trouble is raised as well. If the temperature is increased the tendency to detonation is also increased, and where to compromise is the question.

Another point is that an engine which runs on a certain oil without carbon trouble under a heavy load will, if put into intermittent service occasioned either by much idling or by light loads, show enormously increased carbon deposits out of all proportion to the carbon content of the oil, the oil consumption or any other oil factor.

²⁷ M.S.A.E.—Chief engineer, H. H. Franklin Mfg. Co., Syracuse.

²⁸ M.S.A.E.—Physicist, Bureau of Standards, City of Washington.

²⁹ M.S.A.E.—Engineer, Chicago.

W. R. STRICKLAND²⁸:—What was the temperature of the oil during these tests?

MR. MARLEY:—That of the oil in the reservoir of the machine was 35 and 37 deg. cent., or about 100 deg. fahr.

MR. GRUSE:—With reference to Mr. Parker's remarks regarding the influence of the mixture-ratios, I may say that consideration of our data for the runs with a 10-to-1 ratio shows that enormously greater deposits occur with the richer mixture, a carbon value of 17 against a carbon value of 8. However, the different oils still bear the same relationship to one another; for instance, with the 10-to-1 ratio the Coastal oils gave a carbon value of 8 and the other oils around 16, and with the 12-to-1 fuel mixture the Coastal oils gave 4 and other oils 8. The carbon-value ratio seems to be about the same even though the gross weight of the deposit is different.

OVER-FEEDING OF OIL A CAUSE

CLAUDE S. KEGERREIS²⁹:—A few years ago we ran some tests on carbon deposits and I found that the deposits in the cylinders and on the piston-heads varied directly as the quantity of fuel used. A mixture of 15 to 1 gave a certain weight of carbon and an increase of fuel to 7½ to 1 gave twice as much carbon.

A MEMBER:—The weight of carbon in an engine is in proportion to the quantity of oil burned if all the other variables are kept constant. The thought comes to mind: How far can we go in reducing the oil consumption? Strange as it may seem, I do not know of anyone who can tell us how little oil is required in an engine to replace the oil-film that is burned on the cylinder-wall. The oil that reaches the piston-head and forms what might well be called sticky residue is, I believe, excess oil from the cylinder-wall that is fed up there to give a factor of safety. The surest way to reduce the trouble from carbon residues is to reduce the quantity of oil considerably below that we are now feeding.

Reducing or controlling oil consumption in an engine can be done in many ways but to know them does us no good unless we know how far we can go. While we were making a study of this I found it convenient to express the oil consumption of the engine in terms of the ratio of oil and fuel burned. It is an empiric method but helps to correlate many figures. In using these terms we will find that in airplane-engine practice the average engine now burns about 1 gal. of oil to, say, 20 gal. of fuel. In many automobiles in customary use the gasoline figure is raised to between 50 and 75 gal., and I have

seen some engines that have raised the fuel-oil ratio to 100 to 1 and given satisfaction. The most interesting figure of all, I think, is the average oil consumption of some of the larger Burmeister & Wain Diesel engines of from 1000 to 2000 hp. taken from about 15 ships that had been in marine service for many years. These engines showed a ratio of only 1 gal. of oil to nearly 200 gal. of fuel over the whole period of use. That is enough to signify that we are burning far more oil than is necessary, yet we have evidence all through our repair shops that in the operation of automotive engines the engines do not get enough oil at some periods, particularly when the engines are started cold. We may be on the safe side by throwing a great excess of oil on the cylinder-wall but if we knew how to meter the exact quantity needed at all times and how little oil we could use, I think no more carbon trouble would result from the use of oil.

MR. MARKS:—Our experience may throw some light on the elusive factor just mentioned. The limit to which we can go in reducing oil consumption seems to us to be that point beyond which excessive wear of the parts begins, everything else being equal. In normal summer operation we have found that if a car is driven 2500 or 3000 miles to the gallon of oil consumed, trouble is likely to result. This, I will admit, applies to a particular powerplant. On the other hand, excessive carbon-trouble results if we begin to burn oil at the rate of 1 gal. per 500 miles or less. A happy medium, from considerations of both long engine-life and freedom from trouble, is a rate of 1 gal. to from 1000 to 1500 miles.

MR. STRICKLAND:—I was about to make similar remarks. I should not like to have the impression left that some of us can go much further in reducing oil consumption. Many difficulties arise in the construction and assembly of the product when the oil consumption is reduced very much. On the whole, I think that having carbon collect on top of the piston and in the combustion-chamber is better than far down on the piston where this gummy material collects and which is especially bad on new close-fitting engines and will result in the carbon scoring the cylinders and pistons and ruining the engine.

CHAIRMAN MOUGEY:—We recently made some tests on a car that varied in oil consumption from 1 gal. to about 3000 miles at a speed of about 20 m.p.h. to 1 gal. to about 500 miles at speeds around 50 m.p.h. The automobile engineer must provide enough lubrication at high speeds, and under those conditions he usually has too much at low speeds.

MR. MARKS:—I might add that my figures refer to a touring speed of approximately 40 m.p.h., at which speed the engine turns at about 2000 r.p.m.

²⁸ M.S.A.E.—Assistant chief engineer, Cadillac Motor Car Co., Detroit.

²⁹ M.S.A.E.—Research engineer, Tillotson Mfg. Co., Toledo.

THE ATMOSPHERE ENGINE

THE atmosphere is a vast thermal engine. As Sir Napier Shaw puts it, "partly an air engine but more effectively a steam engine, or at least a moist-air engine, with boiler, condenser and flywheel." A boiler can be found in the heat supply of equatorial regions, the high ice-crowned mountainous Antarctica is an efficient condenser, and as for the flywheel, we have one in the winds. "It was by hanging on to one part of the flywheel in the Fifteenth Century," says Shaw, "that Columbus discovered America, and by the aid of another portion, Alcock crossed the Atlantic in 16 1/2 hr." He makes a guess that the whole energy

of the motion of wind is about 15,000,000,000 kw-hr. or 20,000,000,000 hp-hr.

After all, this is not an appalling quantity, for the physicists of today tell us that 1 gram of hydrogen, which is the quantity in 9 cc. of water, contains something like 6,930,000,000,000,000 ergs, which expressed in more familiar units, is 200,000 kw-hr. As Aston puts it, enough power lies in an ordinary household tumbler of water to drive the great steamship *Mauretania* across the Atlantic and back at full speed.—Alexander McAdie in *Harvard Alumni Bulletin*.

Fields and Requirements for Automotive Equipment in Highway Building

By T. WARREN ALLEN¹

TRACTOR MEETING PAPER

ABSTRACT

POWER is required in large quantity in highway construction. Formerly, horses and mules supplied such as was not furnished by workmen, then steam-power came into wide use, but during the last 5 years motorized equipment has replaced steam equipment to a large extent and is also driving out the horses and mules, notably in drawing graders, excavating, hauling excavated material, and delivering paving materials. Opportunity exists, however, for expansion in this field and for improvement in methods and machines. The field is a large one, in which upward of \$500,000,000 is expended annually. The volume of work and the urge for economy demand that those who are endeavoring to supply the equipment give thought to the special problems and requirements that the work imposes.

While highway construction is an old art, it is not fixed; new facts are being discovered constantly and some new type of equipment may at any time justify new practices in highway design and construction.

The author discusses the opportunities that exist for the use of automotive and motorized equipment for (a) plowing and breaking up the earth, (b) loading it into wheeled scrapers and hauling them to the fill, (c) drawing and operating elevating graders, (d) power excavating, (e) trucking dirt from elevating graders and power-shovels to fills, and (f) hauling paving materials to be placed on the subgrade.

Conditions that surround each phase of the work and the problems they present to the designing engineer are described and suggestions are made as to the types of equipment or the improvements needed to meet the requirements. Among these are

- (1) A power-drawn or a motorized plow having ample power to loosen and break up a large quantity of hard earth per hour
- (2) A tractor with a drawbar pull of from 3000 to 4000 lb. to draw wheeled scrapers while they are loading and to haul them to the fill
- (3) An automotive grader that is self-loading and self-dumping, which calls for a wide power-range, or in its stead some new type of machine for short-haul dirt-removal that is capable of making quick turns on a short radius under adverse traction-conditions
- (4) More direct means of transferring power from a tractor to an elevating grader, or a grader with an independent powerplant for operating the elevating mechanism.
- (5) A crawler-type power-shovel that is capable of moving long distances under its own power without undue wear, or perhaps a shovel built as a tractor-hauled trailer, the shovel to have a bucket of 1-cu. yd. capacity.
- (6) A truck for grading work that can turn on a short radius, has a low weight per inch width of tire, has good traction on soft, rough and often slippery ground, and will stand continued heavy backing-strains
- (7) A light-weight truck of 2-tons capacity and

a road speed of 15 m.p.h. for use in hauling batches of concrete-road material without undue distortion of the subgrade.

For the successful designing of such equipment one should acquire personal familiarity with the problems by direct contact with them where dirt is actually being moved. Coordination of all equipment used on any specific road-job is essential, hence men responsible for the construction and sale of equipment could be very helpful to the users of it by obtaining reliable data on (a) what their particular equipment can accomplish under various conditions, (b) how these results can be obtained and (c) what other equipment a contractor must have to obtain the results that should be secured.

HIGHWAY construction is analogous in many respects to a manufacturing enterprise. Men and machines are used in performing a great variety of operations and power in large quantity is required. In the earlier days, horses and mules supplied such of this power as was not supplied by the workmen. Later, steam-power came into wide use but never entirely replaced the horses and mules. More recently, principally within the last 5 years, motorized equipment has entered this field and in a large measure has replaced steam equipment, is driving out the horses and mules and is even taking the place of manual labor. Thus, at present, tractors are occasionally used in connection with fresno and wheeled-scraper grading-work. Blade graders are now usually drawn by tractors and are sometimes even motorized, and tractors are being utilized in pulling elevating graders. Moreover, trucks are increasingly used in hauling the material excavated by power-shovels and in delivering paving materials of all sorts.

In these fields motorized equipment has displaced or is displacing horses and mules. Steam never was a large factor here, as prevailing boiler-design made steam units too heavy and cumbersome to compete successfully with animal-drawn equipment. Rollers, steam-shovels, cranes, draglines, mixers, crushing plants, and gravel-handling and washing plants, indeed, the whole field of heavy road-building equipment, were formerly all steam driven. Today such equipment is rather generally motorized, so much so, that the presence of other than motorized equipment for most of the work on a road job suggests that the job is a losing venture.

Although motorized equipment may be said to have taken over this large field of road-construction work, in which upward of \$500,000,000 is spent annually, this does not mean that no room remains for further expansion or that either methods or machines have reached that stage of perfection which would justify the conclusion that this is a finished art. Rather, the view I wish to present is that the use of automotive equipment in this field is largely an adaptation, and that better equipment can and will be built. Indeed, the volume of work done in highway construction, as well as the economy with which it should be accomplished, demands

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that those who are endeavoring to supply the equipment give thought to the special problems this work imposes and that by more definitely designing equipment for this field, the problems of those who are working in it shall be simplified.

That changes and improvements will come slowly, is recognized; that is inevitable. I also recognize that, while highway construction is old, it is by no means a fixed art. Indeed, here perhaps as much as in the art of machine design, new facts are being discovered constantly so that what we as engineers believe today we must perhaps reject tomorrow, with the result that equipment that is adequate now may soon be obsolete. Or possibly some new type of equipment will justify new practices in highway design or new methods in highway construction, with the result that a wholly new situation will be presented both to those who build equipment and to those who use it. Therefore, nothing very permanent is in sight in this field, which must, for that reason, be discussed from the viewpoint of prevailing conditions, with the reservation always in mind that tomorrow very different conditions may confront us.

With this view of the subject, we can turn at once to an analysis of at least a few of the problems of highway construction, in the solution of which the service of motorized equipment can be improved and broadened and the work of the highway builder simplified. The first of these problems is that of plowing.

OPPORTUNITY FOR MOTORIZED ROAD-PLOW

Wherever slip scrapers, fresnos, wheeled scrapers and tools of a similar general nature are used by grading contractors, the material that is to be moved must be broken up so that it can be loaded easily. This is a different and a more difficult operation than that performed by a farmer in plowing his field because, after taking off the first layer or two, much heavier and more compact material usually is encountered, and furthermore because turning the material over is of no consequence, the sole objectives being the loosening and breaking up of the soil so that it can be loaded readily. An especially designed plow should therefore be used.

These operations, if adequately performed, require considerable power. On the other hand, if they are not performed adequately, the difficulty of taking on a load reduces both the size of the average load secured and the number of loads drawn per day. An inadequately designed plow is used at present and four, often six, strong mules are required on difficult plowing. Often the work is so difficult that the team must be given a rest after plowing two or three furrows, and as a result the material is neither loosened in sufficient quantity nor properly broken up, hence the output of the carrying equipment is too small. The gross daily load secured per carrying unit; that is, the average individual load times the number of loads drawn, is important, for it is unlikely that an automotive unit that will show a direct operating-cost as low as that of a plow-team can be designed. Rather, to make motorized plowing profitable on an ordinary dirt-moving job, the quantity of plowing done per hour must be sufficiently greater than it is under present practice to enable the contractor to secure a lower cost through using more carrying equipment with each plow and obtaining a heavier load per hauling unit. Well-designed apparatus could readily be made to do both.

A few observations of the performance of farm tractors of the usual type that were tried on this work leave the impression that they are not strong enough to handle it. On the other hand, a 5-ton crawler-type tractor

observed in operation under fairly difficult conditions gave every evidence of having more power than was needed to draw an ordinary plow. From this and other information a satisfactory solution of the plowing problem as met on highway-construction work seemingly could be reached by redesigning the plow and balancing its size against the power-developing capacity of such a machine as a modern crawler-type tractor of moderate size. The plow unit probably should be a series of teeth or narrow shovels rather than the present type of share and mold-board and could well be designed so that the depth of cut could be modified to meet such varying conditions as hardness of soil, depth of cut desired and the like. If, with equipment of this kind, contractors could obtain really accurate data as to the number of carrying units of any particular type for which the plow would provide an adequate quantity of loosened material, a sales field of some importance could be opened with the minimum of ingenuity and effort.

TRACTOR NEEDED FOR WHEELED SCRAPERS

Another branch of the work that could absorb at least a fair number of tractors is the loading of wheeled scrapers. Now the practice in loading these carriers is to use a snatch team of two, three or four mules which, during the loading operation, are hooked in front of the regular wheeler team. Dynamometer readings show that the power required in loading is large as compared with that required in hauling the load. Moreover, repeated measurements made on the load carried by wheeled scrapers indicate that in heavy material the power delivered by even well-selected mules is insufficient to assure a full load. This is not so much because the mules cannot develop the required drawbar pull of from 3000 to 4000 lb. as because it is extremely difficult to get them to pull together. If four mules are used, they ordinarily must be hitched in file by pairs, because a snatch-team hitch of four abreast makes it impossible to work close enough to the bank in cuts of any depth.

Such practical considerations make it commonly true that in materials as stiff clay, coarse gravel and shaley formations, the average load taken out per wheeled scraper is less than in lighter materials such as loam, sandy clay and sand, because not enough power is available to put the load on properly. Only on one job has a crawler-type tractor been found in use in replacement of the snatch-team, and on this job only a limited opportunity was afforded for observing its effectiveness. No final conclusions are possible as a result of this observation but such figures as could be collected rather definitely suggested that the ample power the machine could supply provided a more consistent as well as a larger load per wheeled scraper than was provided by the snatch-team.

Once loaded, the power required for hauling a wheeled scraper is not large. The two mules used for this work could readily haul larger scrapers than those now employed. The objection to the use of larger wheeled scrapers has been the difficulty of properly loading them. Here, then, is an opportunity for some careful study by tractor builders for, if by the use of these machines not only a better load can be had but a bigger wheeled scraper can be used, the economy of substituting tractors for mules could be made apparent to all who are interested.

PRACTICAL DIFFICULTIES OF MOTORIZING SCRAPERS

Some efforts have been made to motorize the fresno and the wheeled scraper. This may prove practical in the case of the fresno if one-man operation is successfully

worked out and ample and effective plowing is assured, but a basic difficulty exists in the case of the wheeled scraper, which may reasonably be given some consideration. The drawbar pull required in loading an ordinary wheeled scraper may reach 4000 lb., although commonly it is about 3000 lb. But during the drag to the dump, which generally is down hill, the drawbar pull required is as low as from 100 to 200 lb., except that considerable extra power must be provided at times, as when soft spots are encountered in the road. More important than this, however, is the fact that our dynamometer studies show that the power momentarily required in dumping a load is almost as great as that required in picking it up. Thus wheeled-scraper operation calls for a wide range of drawbar pull under conditions which make it seem that the engine required would be of a size which would hardly be justified by the size of the load moved.

The fresno and the wheeled scraper are the standard equipment for handling short-haul dirt. No reason exists why some new type of equipment should not be devised for handling such dirt. Considerable short-haul work remains in some parts of the Country although the tendency of design in road-construction equipment seems to be in the direction of vehicles for the longer haul. In designing equipment for handling short-haul dirt, perhaps the foremost problem is to devise equipment that can turn in a short radius in the shortest time. Any hauling that is done in highway-construction work can be expressed graphically in a figure approaching a much elongated ellipse. The turns at the ends of the ellipse must be made on each trip regardless of the length of the haul. On long trips these turns absorb rather a small percentage of the working time, but on short-haul work the percentage becomes relatively high, and on very short hauls, as in fresno hauling from a side ditch onto the roadway, it may exceed 50 per cent of the working day. The conclusion is justified that, while a better tool is needed for short-haul work, to produce one that can compete with the fresno will not prove easy, because a quick turn is difficult under the adverse conditions involved in moderately deep ditches, fairly high fills and mud or soft ground. Moreover to combine the ability to make a quick turn under these conditions with enough carrying capacity to make attractively low the attainable unit-cost on the dirt moved, has not yet seemed possible.

ELEVATING GRADER NEEDS POSITIVE POWER

In grading work, long-haul material is commonly taken out either by an elevating grader or a power-shovel and is hauled by teams or trucks. Any combination of these is basically more economical than the use of fresnos, wheeled scrapers or similar tools because the unit cost of digging and loading is less than that of plowing to break up the soil and then loading, and because the load carried per wagon is much greater than it is per fresno or per wheeled scraper using the same number of horses or mules and their driver. For this reason the proportion of elevating-grader and power-shovel equipment is steadily increasing. Moreover, as engineers come more generally to realize the possibility of reducing costs by designing specifically for wagon or truck haul from elevating graders and power-shovels, the use of such equipment is likely to increase. Therefore, the most attractive present possibilities for motorized equipment in highway-grading work seem to lie in this general field.

The elevating grader is now commonly pulled by a large crawler-type tractor, which merely replaces the horses formerly used for this purpose. The tractor can pull the grader in mud, through swampy ground, in sand and

indeed under almost any condition, but as the grader obtains the power required for elevating the cuttings from a bull-wheel, when the wheel slips the loss of traction stops the elevating mechanism. In practice, the bull-wheel slips considerably even in good ground, hence the rate at which material can be dug and loaded by this combination depends more on the hold that the grader can get on the subgrade than on the power of the tractor. In even a little mud the bull-wheel slips, traction is lost and the work stops. The transmission of power by a bull-wheel always is inefficient, but the really important fact is that the prime mover is more dependable than the machine it is hauling. Some more direct means of transferring power from the tractor to the grader to operate the elevating mechanism is needed, or the grader should have an independent engine for operating the elevating mechanism. This would broaden the field of the elevating grader, as it could then handle sand and light loam better and could work effectively in wet ground where it cannot work at all now.

Considerations of this nature are important to the road-builder, for his profit often depends on the ability of his equipment to function under adverse conditions. The tractor is capable of doing so and its advantage in this field could be increased by solving the problem of utilizing its surplus power and making it something more than a substitute for 16 horses when a contractor purchases it for the purpose of pulling his elevating grader. An arrangement whereby the elevating grader could continue working and store its diggings while an interchange of wagons or trucks is being made would greatly increase its efficiency.

HOW MOTOR-SHOVELS CAN BE IMPROVED

The motor-shovel is entering the field of highway construction so rapidly as a digging and loading tool that no comment on it may seem necessary. Its great advantage lies in the fact that the cost of firing a steam boiler and of hauling water is eliminated. It is also fast and dependable. All shovels designed for highway work are of the full crawler-type. No other type is nearly so well adapted to this work. However, the ability to move these machines long distances under their own power without undue wear of the mechanism, or perhaps as a low-hung tractor-hauled trailer, should be given more consideration.

If the crowding mechanism were improved somewhat it also would be of assistance. In general, this mechanism has not been brought to the perfection attained on steam equipment. Another point that could well be considered is adjustment of the size of the shovel bucket to that of the wagon or truck body. In the past the $\frac{3}{4}$ -yd. machines have dominated the highway field almost to the exclusion of other sizes. Machines of this size take out, in ordinary excavation work, a dipperful which tends to average slightly less than $\frac{1}{2}$ cu. yd. as measured in place. Two dipper-loads make a scant wagon-load, and three dipper-loads cause excessive spillage off of the wagons. The 1-yd. shovel is a more logical size, as two dipperfuls make a good wagon-load. The $1\frac{1}{8}$ -yd. shovel shows a slightly larger average dipper-load. This is not of direct advantage, however, as two full dippers fill an ordinary wagon too full. On the other hand, if the surplus dipper-capacity is utilized in taking on a quick though not always a full load, enough more wagons can be loaded in the ordinary working day to make the extra size very profitable.

The point we desire to stress is that economy in operation demands more than the mere presence on the job

of a good machine. Definite coordination of equipment of various classes is required. That means, in the case of shovels, a careful coordination between the dipper capacity of the shovel and the load capacity of the hauling equipment.

BIG FIELD FOR SHORT-TURNING TRUCK

Wagons are practically always used at present in moving the diggings secured by the elevating grader. They are the dominant type of hauling equipment where power-shovels are used, but trucks are coming into this field. However, speaking in general terms, trucks have proved not altogether successful in this work. This hauling from elevating graders and from power-shovels offers a large open field. Moreover, no valid reason prevents trucks occupying it successfully. The situation seems rather to be one in which a valuable piece of equipment, designed with altogether different purposes primarily in mind, has not proved its ability to meet the special conditions arising in work of this nature. So much of this work is to be done and the life of equipment used on highway-construction work is so short that the volume of business to be had would seem to justify a more serious effort to meet the special conditions prevailing. The grading work absorbs about \$50,000,000 per year on Federal-aid projects alone.

One of the most important conditions that have interfered with a more general use of trucks seems to be their inability to turn on a short radius. The soil from either elevating graders or steam-shovels must be run-out from the cuts into the fills. The fills are narrow, generally from 26 to 36 ft. wide at the roadway level. The cuts may be even narrower, as the shovel can take out only half of a wide cut at a time. With traction in front, as in the case of wagons, a turn on a radius only a few feet longer than the wagon body is possible, but with truck traction on the rear wheels only, a turn as short as this cannot be made successfully in bad ground because the front wheels bind.

Turns on an extremely short radius are perhaps not altogether a necessity, for the width of the working area seldom is less than 20 ft., but the weight of large trucks, which usually is about 10,000 lb. unloaded, is so great that the whole width of the working area seldom is open to them. The shoulders for from 2 to 4 ft. inward from the edge are not, as a rule, so well compacted that trucks can safely venture on them even when empty. This restricts the available width of the working area and correspondingly increases the desirability of a short turning-radius. It also indicates the advisability of a study of the width of tires in connection with the bearing capacity of the ground, to which reference is made later.

BETTER BACKING ABILITY AND TRACTION NEEDED

Greater facility in backing would also increase the value of trucks on grading work. On hauls of less than 500 or 600 ft., to turn a truck around at all should not be necessary. The time spent in turning is a total loss to the contractor. The total quantity hauled per truck per day is reduced by whatever time is spent in turning. Turning around is justified on a long trip by the fact that the return drive can be completed more promptly and with less inconvenience to the other trucks. But on short hauls, and on any sort of grading work, so much of the hauling must inevitably be of the short-haul variety and to turn the truck twice and still make the round trip in less time than it can be made by backing to the dump is so entirely impossible that on well-conducted jobs the short haul would be run-out in this way

if the trucks would stand it. The impression prevails generally, and extended observation seems to confirm it, that the ordinary truck-frame is not designed with heavy constant backing-strains in mind. The mechanical phase of the problem will not be discussed, for my purpose is merely to indicate the requirements, which are greater flexibility and endurance where much continued backing under full load is required. Perhaps other changes in design would also be desirable. An increase in the proportionate length of body to total length of truck would shorten the period in which an elevating grader must be inoperative during interchange of trucks and would be very beneficial.

Another aspect of the problem is that of maintaining traction on difficult ground. When fully loaded the truck and its load may weigh 10 tons or more. Most of this weight is on the rear wheels and as a result the load per inch of tire width is high. Perhaps of even more importance than this is the fact that the concentration of gross weight per wheel is high. The problem presented here is serious for a fill in the making must inevitably be somewhat unstable. Generally it is rough, soft spots are bound to exist, often it is slippery; but operations must continue in spite of such conditions. For me to attempt to point out a solution of the problem would hardly be appropriate. That should be developed by those who make designing a specialty. I cannot, however, refrain from stating that I think the problem can be solved. This is the largest field that is still unoccupied by automotive equipment. The horse and the mule dominate it today because they are well adapted to meet prevailing conditions on dirt-moving jobs; these are, a narrow working-area and ground that is soft, rough and often slippery. That this domination will yield at once to automotive equipment when such equipment is designed specifically to meet these conditions is my firm conviction. To design a successful truck for the purpose, however, will require such a personal familiarity with these problems as can be had only by considerable direct contact with them where dirt is actually being moved.

LIGHT 2-TON TRUCK WANTED FOR CONCRETE PAVING

Trucks have completely driven out the horse and mule in the paving field and have all but eliminated the industrial railway. Room for improvement in small-truck design exists at present, however, particularly in the concrete-paving field. The two-batch trucks, particularly when equipped with dual pneumatic tires, are doing excellent work in a very satisfactory manner.

The problem is one of carrying the present standard load, which is a six-bag batch that weighs about 2 tons, without undue distortion of the subgrade. Large multiple-batch trucks never have been able to do this, as the rear-wheel load has been too high. Even the two-batch truck has met some opposition because of this but seems to meet the situation to the general satisfaction of highway engineers when equipped with dual pneumatic rear tires. However, the popular truck for this work always has been the light single-batch truck, but this was seriously overloaded when the five-bag batch was standard and is even more seriously overloaded now that the six-bag batch has become the standard in concrete paving-work. A light truck designed to carry a 2-ton load at a practical road-speed of about 15 m.p.h. would be of great assistance to highway contractors and should reduce considerably their annual loss through depreciation in hauling equipment.

In highway work, as in so many other fields, economi-

cal production depends to a great extent upon coordination. That a contractor have good equipment is not enough. He should also have coordination of equipment throughout his job set-up. Men who are responsible for the construction and sale of road-building equipment would do much for those who must use it if they would obtain, even if at considerable cost, reliable data on (a)

what the equipment offered can accomplish under various conditions, (b) how the results can be accomplished and (c) what other equipment a contractor must have to obtain the results that should be secured. Much good equipment makes a poor showing in the field solely because of a vital failure in coordination due to the fact that data of this sort are not available.

THE HAND SIGNAL

ONLY a very few laws help the operator to determine what is and what is not a proper hand-signal. The decision is left to his imagination and ingenuity. The usual practice shows little or nothing of any actual purpose or intention but only that the operator who gives the signal will make some unspecified change in his operation. In other words, the hand signal in its present execution is cautionary; and, so far as reliance can be placed upon it, except in unusual cases, it stops there. Any person for whom a signal is given, except rarely, is justified only in waiting to see what will develop; he cannot safely assume that he knows from the given signal exactly what operation will follow.

While this is the situation today in almost every part of the Country, *there is no reason why it should be.* This must be corrected and it is high time that a long step in advance be made so that a definite hand-signal shall be required to be given for each action to be taken. No difficulty in prescribing this exists; in fact possibly too much material is at hand.

A signal need not be given unless someone is there to take it or to be affected by it. In a time when practically every car is equipped with a mirror giving a view to the rear, for each operator to exercise judgment in the giving of hand signals is right. He may use them to supplement his mechanical signal, if he has one, remembering that the mechanical signal is not endowed with intelligence, while he presumably is. He is able by the correct use of his hand to express his intent and that is what should be required of him. The hand signal will inevitably show two results; one that the mind of the operator giving it is focussed on the performance about which he is signalling, and the other what that performance will be.

THE EASTERN SYSTEM

In the East, education in definite signals has been attempted but not as extensively or as thoroughly as is necessary. Long ago each Eastern State, through its proper official, either specified or tacitly agreed what each hand-signal shall indicate, and some attempt has been made to differentiate so that the intention of an operator may be explicitly expressed by such signal and reliance placed upon it by those for whom it is given. A code can be prescribed for the East which would embody the benefit of all the teaching and experience now in existence. This is as follows:

General.—For the giving of all hand-signals extend the arm horizontally at full length. Do not drop the arm down, for often the construction of the car is such that no hand, unless well out, will show. All signals should be given sufficiently in advance of the action to be of use to all who need to heed them.

Stop or Slow.—Extend hand and arm horizontally and hold it rigid. This signal is given generally for almost any intended purpose. It is the cautionary signal in practice today. In comparison with the other two signals commented upon, it is a still signal, while the others are motions; so it cannot be confused with either of them. It is the signal that should be used to

show the following car an intention to slow down or stop.

Turn Left.—Pointing motion with index finger. To indicate intention to turn to the left, pointing with the index finger has been used with success. Objections are raised to this form as being too particular; that to separate the index or pointing finger from the hand is too difficult for performer or the observer and that this signal can thus be mistaken for the slow signal. This objection is valid but can be met by a pointing motion. In the most congested traffic of the world, in New York City, Chicago and similar cities, professional drivers have come to this motion pointing-signal as the most effective and least apt to be mistaken. The pointing motion is obviously a great improvement over the still finger, for it shows active mind action, and it makes little or no difference whether the index finger is seen or not, provided the up-and-down motion is discernible. This is a clear understandable signal.

Turn Right.—Rotate hand forward from wrist or elbow. This is another signal evolved by necessity. It clearly means to the operators following, "I am going to turn right," or "You may pass on my left." It cannot be mistaken. It has all the advantages the moving-left signal presents and shows that the mind of the operator giving it is made up and clearly indicates what will be done.

Backing.—No backing-signal seems to be necessary. One was prescribed in early codes, but it seems likely that it has never been given by anyone because backing takes all the attention of an operator and is so unusual a driving act that each operator carefully observes what is around him before he backs. No backing-signal is at present recommended.

THE WESTERN SYSTEM

In the West, especially in California, a different code is in use. I understand that this code is a semaphore system and that it is as follows:

Extending the arm downward means "stop."

Extending the arm horizontally and holding it rigidly means "turn left."

Extending the arm upward means "turn right."

This system is a part of some laws and is often discussed by observers as being effective and accurate. While I am not qualified by observation to judge performance in obedience to this code, it seems to me that if it were in effect in Connecticut, the confusion between the "stop" and the "turn left" signals would be very great. Most hand-signals seen in Connecticut are similar to the Western stop-signal and might mean anything.

It is often necessary to indicate to an officer where one expects to go and then to wait for his direction. This signal ought to be exact. The Eastern code meets this condition.—R. B. Stoeckel, motor-vehicle commissioner of the State of Connecticut.



Industrial Application of Tractors

By WILLIAM PARRISH¹

TRACTOR MEETING PAPER

Illustrated with PHOTOGRAPHS

ABSTRACT

THE industrial application of tractors is a recent activity that has been stimulated by the desire to make such an abundance of power serve the year round. Already it has found many diversified uses in the lumber industry, coal mining, the transportation of materials about manufacturing plants, the handling of freight in railroad warehouses, and, in general, wherever short hauls of bulky materials are required. A number of these applications are described and the adaptability of the tractor to use under diverse conditions is explained.

BETTER methods of doing work must be adopted if industry is to survive in competitive fields. This adoption may not be immediate; sometimes even the best of ideas are slow of acceptance, yet approximately 12 per cent of the total production of tractors has been devoted to uses other than agricultural. The industrial application of tractors is a recent activity that has been stimulated by the desire to make such an abundance of power serve the year round.

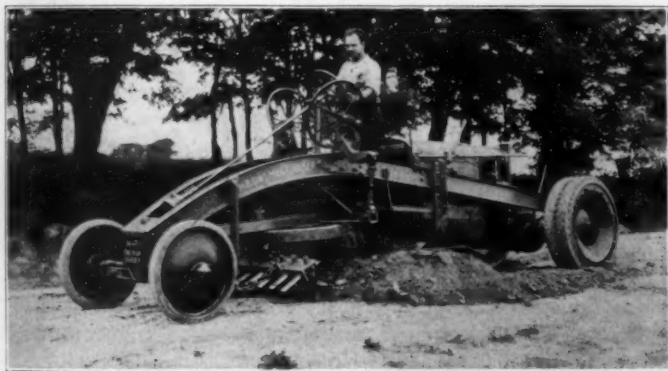


FIG. 1—INDUSTRIAL TRACTOR USED IN GRADING
One-Man Maintainers of This Type Are in Use in Many States

In road work, motorized maintainers are used in the highway department of practically every State, the State of Missouri, in one small district alone, operating 22 tractors of 10 to 20 hp. and 29 machines of 15 to 30 hp. California has recently purchased 105 industrial tractors in one-man graders, of the type shown in Fig. 1, and Iowa, 42; while Florida, on her worst roads, is using 22-in.-wide rubber-tired rear-wheel tractors, like the one illustrated in Fig. 2. In construction work, tractors are being used in all operations, from the original dirt road to the finished concrete or macadam surface. Two examples of such use are given in Figs. 3 and 4. Their power is consistent, their maintenance low and their operation very economical.

The popularity of the industrial tractor is increasing in every branch of the lumber industry. In camps to which access was impossible under previous methods, skidding and log-loading operations culminate only with the final pulling of the stumps in a land-clearing project. By the running of saws in the mountainous or the



FIG. 2—RUBBER-TIRED REAR-WHEEL TRACTOR
The Wheels Are 22 In. Wide. Roads Are Scarified by Heavy-Duty Tractors at a Cost of \$13 per Mile as Compared with the Usual Cost of \$50

marshy and valley tracts, operable only by a portable powerplant that is independent of a water supply, abandoned acreage is being reclaimed. In yards and mills, many types of equipment for hauling and lifting have been made available by ingenious inventors, even by manufacturers themselves; and, finally, in making delivery, specially designed semi-trailers unload the pile of lumber as a unit, the deck breaking and tipping when the load is rolled back of the center of gravity over the rear axle. Truly the uses to which tractors are being put in this one field alone are worthy of recognition.

In the coal industry, at the mines, on the loading-docks, in yards, or for plant coal-piles, and even for delivering coal to customers, industrial tractors are proving time, labor and money-savers. Practical and efficient equipment is available in the form of conveyors, clam-shell hoists and loading-devices operated by winches connected with power take-offs; and for hauling large loads, gravity dump-bodies on both two and four-wheel trailers



FIG. 3—TRACTOR DRAWING CRAWLER ATTACHMENT IN ROAD CONSTRUCTION
In This Case the 3½-Ton Detachable Scarifier Has Fully 8 In. of Penetration

¹Sales department, International Harvester Corporation of America, Inc., Chicago.

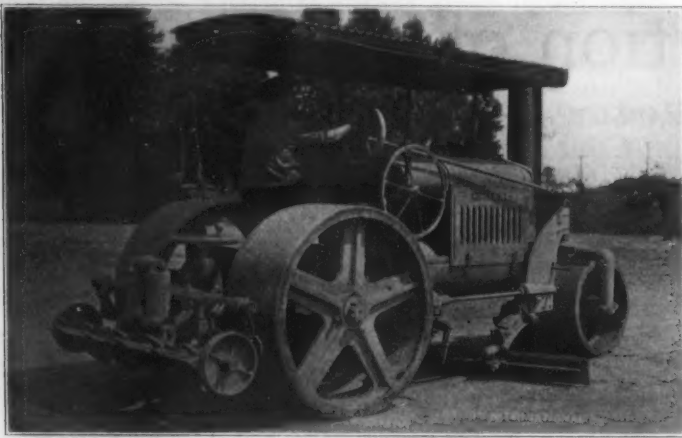


FIG. 4—SMOOTHING THE ROAD

This Type of Tractor Powerplant Can Handle as Much as 10 Tons

are used. The tractor is proving essential for the reason that it fills economically a need that no other motive-power unit has so far attempted to fill.

The Nation's Business, a few months ago, was authority for the statement that American manufacturers spend more money for the moving of materials within their plants than for rail and motor-truck freight combined. The industrial tractor can help these men to cut the cost of haulage by the use of four-wheel trailers for moving freight and for delivery; by distributing materials and parts from the stock-piles to the plant, as shown in Fig 5, and even to individual machines; by hauling material directly to the loading-docks and dumps; and, finally, in moving the loaded freight-cars and spotting the empty ones. The handiness of the short wheel-base, combined with mechanical simplicity and continuous service, makes tractor power a very decided factor.

All the large railroad companies, including the Illinois Central, the Monon, the Chicago, Burlington & Quincy, the Northern Pacific, the Nickel Plate, and the Southern,



FIG. 5—TRANSPORTING MATERIAL IN INDUSTRIAL PLANTS
A Remarkable Variety of Trailer Types Are Adaptable to This Work

as well as the Pullman Co. have shown very decided savings both inside and outside their plants.

Transportation engineers agree that about 10 times as much power, roughly speaking, is required to propel motor-trucks, tractors, or any other motorized unit, up a 10-per cent grade as on a level road; also, that from 5 to 25 times as much power is required to propel the same unit over a poor road as over a concrete, a brick or an asphalt pavement. We know what tractor power is; on medium to good roads, therefore, and with fair grade conditions, a semi-trailer, one type of which is shown in Fig. 6, can be used with an industrial tractor to supply weight to the rear wheels for traction. If desired, the semi-trailer can draw another four-wheel trailer and, even then, will operate well within the maximum capacity of the tractor. What is more important, the combination will also be within the law as to tire weight.

Because of the great variety of influencing conditions, no fine distinction can be drawn between the transportation work of tractors and that of motor-trucks. In general, however, we may say, for short hauls of heavy bulky materials, the tractor excels even the team and the dray. The excessive cost involved, when expensive equipment must stand idle during loading, is overcome by having a powerplant in the form of a tractor constantly



FIG. 6—SEMI-TRAILER USED IN THE WAREHOUSE AND STORAGE BUSINESS

These Unique Vans Have Made Trips as Long as 500 Miles

hauling several trailers. In that case neither the operator nor the unit incurs any loss of time in accumulating or discharging loads.

The tractor is a most mobile form of powerplant under adverse conditions. It makes the short quick turns that are necessary in industrial plants and, owing to its excellent gear-reduction and distribution of weight, negotiates bad going. It is a versatile unit subject to a variety of combination attachments that can be used for a far greater number of purposes than can those using any other motive power. One user has stated that his tractor is "A jack-rabbit for speed, an elephant for power and a bear for work."

The industrial tractor should gain attention through your knowledge of the many machines applicable and actually in use. The possibilities of this untouched market should prove of interest.



Causes of Wear and Corrosion in Engines

By OTTO M. BURKHARDT¹

SEMI-ANNUAL MEETING PAPER

Illustrated with CHARTS

ABSTRACT

THE paper represents a study of analyses obtained from 656 samples of contaminated crankcase-oil and states the results of cooperative research, the sponsors being the Society, the American Petroleum Institute, the National Automobile Chamber of Commerce, and the Bureau of Standards. Reliable information was sought regarding existent conditions throughout the Country and, since analyses of a large number of samples were a requisite, arrangements were made with service stations located at points representative of the Country's atmospheric and geographical conditions for the collection of samples of contaminated crankcase-oil, a uniform procedure calculated to assure accuracy of the results being enjoined. Each participating service station was requested to select 10 cars, all of the same make, to drain the oil and to refill with new oil. After the cars so prepared had run a distance equal to that commonly allowed for one filling of oil, the oil was to be withdrawn into a clean container immediately after stopping the engine. From this well-mixed crankcase-draining an 8-oz. sample was to be sent in a glass container to the Bureau of Standards for analysis. The trade names and the grade of new oil used were to be recorded in all cases.

Some of the influential factors that could not be controlled in a survey of this kind were the make of engine, the age and the condition of the engine, the service that a car was rendering, the care and attention that was given to the engine, and the quality of the lubricant. The statement is made that, in general, the number of samples so far analyzed is not large enough to permit the drawing of clearly definite conclusions and that, therefore, definite answers to some of the questions propounded by the Steering Committee cannot be given. But since much valuable information can be secured from the analyses made thus far, the data are presented so that this information may become available.

The method of analysis used by the Bureau of Standards is described and the data obtained from the 1925 and the 1926 surveys are explained. Subjects such as the pathology of the internal-combustion engine, tracing causes of contamination by ingredients found in the ash, and the influence of various factors on contamination are discussed. Other parts of the paper have to do with the grouping of samples according to iron oxide, the relation between silica and iron oxide, the effect of mileage on the silica-iron oxide relation, qualifications of the influence of mileage on contamination, and the effect of viscosity on the accumulation of iron oxide.

After making tabular diagnosis of some of the 1926 samples, the author outlines the effects of temperatures and explains the data showing that the silica content of the 1926 samples indicates little cause for wear. He discusses the effect of a high percentage of sulphur in the fuel, the significance of ash and the effect of air-cleaners and oil-filters. A comparison is made between the results of the 1925 and the 1926 surveys and the differences of dilution for the various groups of samples are analyzed. Factors influencing the accumu-

lation of water are enumerated and the tabular data pertaining thereto are explained. In conclusion, the suggestion is made that the interpretation of the data obtained in this extensive survey can be elaborated, and that such elaboration be undertaken by universities.

THE lubricating-oil is as important to the proper functioning of an internal-combustion engine as any structural part. That of all the materials and finished units entering into the construction of a complete engine none changes its characteristics so rapidly as the oil is also recognized. This shortcoming is well known to the majority of designers and oil refiners and, for this reason, specifications have been established after lengthy discussions to the end that lubricants shall meet with some certainty of endurance the variable conditions encountered in the operation of engines for motor-vehicles. However, any oil, even though manufactured to meet the most exacting specifications, after it has been used for only a short time becomes admixed with contaminating substances, and because of this its physical characteristics change so radically that the best salesman could not, after it had been used for only 1 hr., sell it to a discriminating car-owner for 5 cents per gal. One of the reasons for this is that the oil will not meet the customary requirements regarding color, flash-point, viscosity, freedom from asphaltic substances, and acidity. While this does not imply that the oil itself or even a substantial portion of it has been rendered useless after such limited service, it will help to illustrate the great need for research on contaminated oil.

Contaminated oil can be rectified. This is done very successfully in many branches of engineering. In the Air Service during the World War, a necessity existed for the conservation of lubricating-oil. Therefore, a system of reclamation was instituted and in tests recorded by William F. Parish¹ in a paper on the Proper Balancing of Fuel, Lubricant and Motor², it is stated that reclaimed oil was found to be, if different in quality, a better lubricant than new oil. Engines have been found to remain cleaner with used oil than with new oil. Fifty per cent of the engineers at the flying-fields are quoted in this paper as stating that reclaimed oil was preferred to new oil, while the other 50 per cent found that it was just as good.

The rate of contamination during use and the appraisal of the usefulness or the possible harm of contaminated lubricating-oils is at present a matter of opinion and conjecture. Very few quantitative data on that subject can be found in the literature. Experience and records indicate, however, that instances of poor performances and much of the maintenance cost incidental to the use of internal-combustion engines can be traced directly to unsuitable lubrication. Engineers know that the various ingredients commonly found in contaminated oil, such as silica, iron oxide and abraded metal particles, act as abrasives. This is particularly so if fuel has become admixed with the oil and has reduced its viscosity to the extent that the sliding surfaces are

¹ M.S.A.E.—Research manager, Society of Automotive Engineers, Inc., New York City.

² See *Mechanical Engineering*, March, 1920, p. 164.

not kept far enough apart to prevent abrasives from scratching, or that the oil-film breaks down entirely and metallic contact and perhaps seizure takes place. For instance, that the piston-rings of tractor engines have worn-out in about 10 hr. because the air entering the combustion-chamber was loaded with silica is well known. If water is present together with other impurities, then the oil forms sludge that clogs screens, filters and other oil-passages and consequently interferes with free circulation.

SOME EFFECTS OF DILUTION ON OIL

Of all the contaminating elements, dilution, only, has so far been given much attention by authorities. In spite of this conclusions regarding the effect of dilution on wear and on the general factor of safety against the breaking down of the oil-film apparently have not been enunciated, at least in such form as would be generally acceptable. We note that at present some designers take great precautions to prevent dilution, while others entirely ignore it because of a reliance on the self-regulating effect it has on the viscosity of the oil. That highly viscous oils make starting in cold weather extremely difficult and in some cases impossible is well known. Under such conditions, dilution has proved of benefit insofar as it reduces the viscosity and helps to prevent the oil from congealing. It further assures quick circulation of the oil after starting in cases where the undiluted oil is likely to congeal at low temperatures.

Because of the diversity of opinions relative to dilution and contamination as expressed through current practice and on account of the fact that dilution is likely to be as harmful as it may be useful, quantitative research-data on the subject of oil contamination in general obviously are greatly needed. From such quantitative data to determine what percentages of contaminating substances are tolerable for the various viscosities that are likely to be obtained with the oils generally used should be possible.

COOPERATIVE RESEARCH INSTITUTED BY THE SOCIETY

The Society, early in 1925, through its committees and particularly upon suggestion by H. C. Mougey, chairman of the Lubricants Division of the Standards Committee, undertook to organize some researches on contaminated crankcase-oil. Financial assistance for a research project of this nature was to be given by the American Petroleum Institute and the National Automobile Chamber of Commerce, while the carrying out of the necessary laboratory work by the Bureau of Standards was assured. The desire of the Steering Committee was that the investigation should be directed so as to find answers to certain specific questions propounded by the Committee. The most important object of the survey, however, appears to have been to secure reliable information as to the actual conditions of crankcase-oil contamination existing throughout the Country.

That a very large number of contaminated-oil samples would have to be collected and analyzed if reliable conclusions were to be expected was realized. For this reason arrangements were made early in 1925 with eight passenger-car and motor-truck builders that each of them would select six or eight service stations located in cities that best represent the various atmospheric and geographical conditions of the Country. Localities from which complaints of engine depreciation were known to have come to many companies, if not all, were included. These carefully selected service stations were then approached with the request to cooperate in the collection of samples of contaminated crankcase-oil. To assure

accuracy of the results, it was necessary to induce all participants to follow a uniform but simple procedure in the collection of these oil samples.

All participating service stations were requested to select 10 cars, all of the same make, to drain the oil and to refill with new oil. After the cars so prepared had run a distance equal to that commonly allowed for one filling of oil, the oil was to be withdrawn into a clean container immediately after stopping the engine to prevent precipitation of ingredients. From this well-mixed crankcase-draining an 8-oz. sample was to be taken at once and forwarded in glass containers to the Bureau of Standards in the City of Washington. Glass containers and other facilities were furnished by the Society. The trade-names and the grade of the new oil were to be recorded in all cases. This paper represents a study of analyses obtained from 656 samples of contaminated crankcase-oil. In later work, samples of the fuel used were also requested.

FACTORS LEFT UNCONTROLLED IN THIS SURVEY

Motor-car engines are subjected not only to normal and to abnormal wear but also to corrosion. These phenomena are in turn influenced in varying degree by a large number of conditions that could not be controlled in a survey of this kind. Some of these influential factors are given in the following list:

- (1) *Make of Engine.*—Structural differences, such as bearing clearances, efficiency of the lubricating system, quality of workmanship, and the hardness and other physical characteristics of the bearing-surfaces. Oil consumption and, consequently, the rate at which oil is replenished in service, have of course an influence on the state of purity at which the oil will be found when it is drained after a certain mileage.
- (2) *Age and Condition of Engine.*—New engines may show a higher rate of abrasion and more metal particles in the oil than well-worn-in engines for the reason that the surfaces after grinding and honing are still serrated with fine ridges that wear off in a relatively short time. Loose particles that adhere to new bearing-surfaces become washed off with use. Only after several thousand miles of running do cylinder-walls and bearing-surfaces become highly polished; the latter condition, of course, helps to reduce wear.
- (3) *Service That a Car Is Rendering.*—Cars employed in light work will not, if other conditions are alike, show as much wear as others that are used for heavy-duty purposes. Moreover, cars subjected to continuous running are not subject to as much corrosion and its consequent disadvantages as are others that are used intermittently. Many engineers are convinced that most of the wear occurs immediately after starting, when the lubricant has drained off from the surfaces and the latter have started to corrode because of the presence of water, acids and air.
- (4) *Care and Attention Given to the Engine.*—Oil in use is becoming diluted with fuel. This action is particularly marked when rich mixtures are used such as are necessary for starting and warming-up in winter. Engines that are kept in warm garages should therefore suffer less deterioration than those kept in cold garages or out of doors.
- (5) *Quality of Lubricant.*—When starting, and under certain running conditions, some important surfaces may slide relatively to each other with a ruptured film between them. When this takes place the oiliness factor of the lubricant becomes very important and determines abrasion.

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TABLE 1—ANALYSES OF THE 1925 OIL SAMPLES

Supplied Data					Examination of Used Oil										Chemical Analysis of Ash Proportion of Used Oil by Weight, Per Cent											
Groups Designating Make of Car	Identification Number	Number of Samples in Compound	Locality	Time during Which Samples Were in Service	Fuel Used	Oil Identification Number	Proportion of Used Oil by Volume, Per Cent			Proportion of Used Oil by Weight Per Cent						Ash	Iron Oxide	Copper Oxide	Tin Oxide	Lead Oxide	Metals	Silica	Silica from Iron	Other Compounds		
							Dilution	Water	Insolubles	Asphaltenes	Carbon	Ash	10	11	12										13	14	15	16	17	18	19	20	21	22
A	C-1 C-2	3 6 11	Atlanta Detroit	4/8 4/1-30	Gasoline Gasoline	133, 134 and 135 Miscellaneous Weighted mean	8	19.0	0.80	0.638	0.027	0.424	0.187	0.1720	0.1452	0.0040	0.0020	0.0000	0.0000	0.0000	0.1512	0.0188	0.0130	0.0020		
							20.0	Trace	0.633	0.105	0.286	0.242	0.2430	0.1652	0.0080	0.0032	0.0000	0.0000	0.0000	0.0000	0.1764	0.0352	0.0286	0.0498		
B	C-5 C-3 C-4 C-6 C-27 C-7	12 17 4 9 7 10	Birmingham Detroit Detroit Minneapolis Oakland Oklahoma City	4/20-5/25 3/20 3/20 4/5-5/20 4/1-5/18 4/1-5/1	Benzol blend Ethyl gas Gasoline Not given Gasoline Gasoline	300 35 35 326 and miscellaneous 169 and miscellaneous Miscellaneous Weighted mean	8	16.0	Trace	0.546	0.054	0.270	0.222	0.2210	0.1712	0.0060	0.0036	0.0000	0.0000	0.1808	0.0228	0.0159	0.0274			
							15.5	Trace	0.302	0.046	0.140	0.116	0.0910	0.0866	0.0224	0.0056	0.0000	0.0000	0.0000	0.0676	0.0108	0.0084	0.0126			
C ^a	C-9 C-8 C-23	8 10 7	Birmingham New Orleans Oklahoma City	4/1-4/28 3/1-5/15 5/12-6/25	Benzol blend Gasoline Gasoline	108B, 302, and 303 Miscellaneous Weighted mean	8	13.0	Trace	0.490	0.036	0.378	0.066	0.0780	0.0580	0.0020	0.0020	0.0000	0.0000	0.0620	0.0030	0.0007	0.0130			
							13.0	Trace	0.386	0.040	0.255	0.073	0.0750	0.0540	0.0020	0.0020	0.0000	0.0000	0.0000	0.0630	0.0040	0.0018	0.0090			
D	C-22	4	Oklahoma City	4/6-6/28	Gasoline	Miscellaneous Weighted mean	8	13.0	0.00	0.219	0.052	0.119	0.048	0.0540	0.0320	0.0030	0.0030	0.0000	0.0000	0.0390	0.0080	0.0067	0.0070			
							13.0	Trace	0.362	0.042	0.257	0.064	0.0702	0.0492	0.0023	0.0023	0.0000	0.0000	0.0000	0.0555	0.0048	0.0028	0.0097			
E	C-11 ^b C-12 C-14 C-10 C-13	3 7 10 10 10	Birmingham Birmingham Detroit San Francisco Tulsa	3/5-5/1 2/21-4/7 3/14-6 4/1-5/2 3/16-20	Benzol blend Benzol blend Gasoline Gasoline Gasoline	108A 304 246 5 Weighted mean	8	11.0	Trace	0.259	0.061	0.106	0.092	0.0960	0.0640	0.0020	0.0050	0.0020	0.0020	0.0730	0.0080	0.0054	0.0150			
							11.0	0.00	0.259	0.061	0.106	0.092	0.0960	0.0640	0.0020	0.0020	0.0000	0.0000	0.0000	0.0730	0.0080	0.0054	0.0150			
F	C-25 C-26 C-15	12 10 10	Detroit San Francisco City of Washington	7/20 5/1-7/1 4/18-5/20	Gasoline Gasoline Gasoline	Heavy Miscellaneous Federal specification Weighted mean	8	10.0	0.00	0.358	0.018	0.260	0.080	0.0890	0.0510	0.0020	0.0030	0.0000	0.0000	0.0560	0.0240	0.0220	0.0090			
							10.0	0.20	0.338	0.022	0.546	0.270	0.2860	0.1990	0.0050	0.0110	0.0000	0.0000	0.0000	0.2150	0.0340	0.0460	0.0150			
G	C-24	9	New Orleans	3/25-6/24	Gasoline	Weighted mean	15.5	0.25	0.430	0.046	0.271	0.113	0.1140	0.0650	0.0020	0.0090	0.0050	0.0050	0.0810	0.0060	0.0034	0.0270				
							9.0	0.00	0.625	0.021	0.444	0.079	0.1160	0.0680	0.0010	0.0050	0.0000	0.0000	0.0000	0.0730	0.0060	0.0033	0.0370			
H	C-16 C-17	11 6	Birmingham Detroit	3/18-3/27 2/9-3/31	Benzol blend Gasoline	48 306 Weighted mean	14.5	Trace	0.404	0.021	0.293	0.090	0.0900	0.0600	0.0000	0.0040	0.0000	0.0000	0.0670	0.0090	0.0066	0.0240				
							12.2	0.538	0.047	0.367	0.124	0.1392	0.0808	0.0025	0.0067	0.0013	0.0071	0.0165	0.0130	0.0254						
I	C-18	11	Detroit	3/1-5/16	Gasoline	Weighted mean	8.5	0.00	0.272	0.067	0.157	0.048	0.0430	0.0320	0.0020	0.0020	0.0000	0.0000	0.0380	0.0030	0.0017	0.0040				
							7.5	Trace	0.946	0.338	0.378	0.224	0.2600	0.1800	0.0030	0.0150	0.0000	0.0000	0.0000	0.2040	0.0380	0.0286	0.0200			
J	C-19	10	San Francisco	4/18-5/20	Gasoline	Weighted mean	5.5	0.10	0.285	0.053	0.162	0.070	0.0550	0.0400	0.0020	0.0040	0.0000	0.0000	0.0460	0.0060	0.0044	0.0030				
							7.3	0.485	0.147	0.228	0.110	0.1145	0.0837	0.0025	0.0067	0.0000	0.0073	0.0139	0.0110	0.0087						
K	C-20 C-21 C-19	5 5 11	Birmingham Birmingham San Francisco	3/23-5/5 2/16-5/1 4/8-5/5	Benzol blend Gasoline Gasoline	305 305 132 Weighted mean	22.0	0.10	0.441	0.066	0.221	0.154	0.1610	0.1000	0.0020	0.0050	0.0040	0.0040	0.0040	0.1110	0.0340	0.0300	0.0160			
							22.0	0.00	0.441	0.066	0.221	0.154	0.1610	0.1000	0.0020	0.0050	0.0040	0.0040	0.0040	0.0040	0.1110	0.0340	0.0300	0.0160		
L	C-22 C-23	11 6	Birmingham Detroit	3/18-3/27 2/9-3/31	Benzol blend Gasoline	48 306 Weighted mean	15.5	0.00	0.674	0.059	0.447	0.168	0.1600	0.1480	0.0020	0.0020	0.0000	0.0000	0.1500	0.0070	0.0011	0.0120				
							14.0	Trace	0.356	0.023	0.186	0.147	0.1510	0.1270	0.0040	0.0010	0.0000	0.0000	0.0000	0.1310	0.0070	0.0020	0.0130			
M	C-24 C-25	15.0 18.0	Detroit	3/1-5/16	Gasoline	Weighted mean	15.0	0.60	0.562	0.046	0.354	0.160	0.1625	0.1405	0.0027	0.0004	0.0000	0.0000	0.0000	0.1430	0.0070	0.0014	0.0123			
							18.0	0.60	0.525	0.090	0.299	0.136	0.1540	0.1000	0.0060	0.0030	0.0030	0.0030	0.0030	0.0030	0.1120	0.0040	0.0000	0.0180		
N	C-26 C-27	18.0 20.0	Detroit	3/1-5/16	Gasoline	Weighted mean	18.0	0.60	0.525	0.090	0.299	0.136	0.1540	0.1000	0.0060	0.0030	0.0030	0.0030	0.1120	0.0040	0.0000	0.0180				
							20.0	0.60	0.525	0.090	0.299	0.136	0.1540	0.1000	0.0060	0.0030	0.0030	0.0030	0.0030	0.1120	0.0040	0.0000	0.0180			
O	C-28 C-29	16.0 20.0	Birmingham Birmingham	3/23-5/5 2/16-5/1	Benzol blend Gasoline	305 305 132 Weighted mean	16.0	0.20	0.908	0.069	0.543	0.294	0.2950	0.2270	0.0060	0.0020	0.0050	0.0050	0.2500	0.0140	0.0046	0.0310				
							20.0	0.00	0.538	0.038	0.336	0.164	0.1570	0.1480	0.0040	0.0000	0.0000	0.0000	0.0000	0.1520	0.0060	0.0001	0.0010			
P	C-30 C-31	20.0 11	San Francisco	4/8-5/5	Gasoline	Weighted mean	20.0	0.00	0.511	0.042	0.335	0.134	0.1510	0.1180	0.0050	0.0020	0.0020	0.0020	0.1250	0.0090	0.0043	0.0170				
							18.1	0.612	0.048	0.384	0.179	0.1870	0.1536	0.0040	0.0015	0.0022	0.0022	0.0022	0.0022	0.1605	0.0095	0.0034	0.0160			
Q	C-32 C-33	14.6 11	Detroit	3/1-5/16	Gasoline	Weighted mean	14.6	0.484	0.064	0.274	0.147	0.1515	0.1075	0.0035	0.0051	0.0012	0.0012	0.1178	0.0167	0.0122	0.0169					
							.....	.....	13.2	56.4	30.4	.....	71.0	2.3	3.4	0.8	77.5	11.0	8.0	11.2			

^a Air and oil filters were used on the cars comprising this group.
^b Air-cleaners used for this compound only.

STUDY OF A LARGE NUMBER OF SAMPLES YIELDS RESULTS

Any attempt to place the control of some or all of the foregoing factors upon the participating service stations would, of course, have been absurd. However, in spite of all these variable and uncontrollable factors conducting a survey by collecting samples of oil from motor vehicles run under conditions fairly representative of those to which the 20,000,000 vehicles in service throughout the Country are subjected appeared entirely justifiable. Great differences in the usage of cars, while affecting individual results, can be averaged and balanced if a very large number of results are available. Further, inasmuch as differences in usage exist throughout an entire year, a change in the season can reasonably be expected to exert a predominating influence on the averages, irrespective of the other factors already mentioned. To determine the seasonal influence at least two major groups of samples should be available for analysis; namely, one group taken from oil that has been in service during the winter months and another taken from oil that has been in service during the summer months. Summer samples have not been collected, as was suggested. Weather conditions existing during the collection of the two series of samples, however, have covered a somewhat wide range.

In this connection it may be stated in general that the number of samples so far analyzed is not at all large enough to permit drawing clear conclusions. Therefore, definite answers to some of the questions propounded by the Committee cannot be given in this paper. Inasmuch as the continuance of the whole program is at present problematical and as it is thought that much valuable information can be secured from the analysis as made thus far, the material is presented herewith in the form in which it will be submitted by the Society's Research Department to the respective committees for final action.

Samples collected in the spring of 1925 were carefully indexed as they arrived at the Bureau of Standards. To

reduce the number of analyses and to make samples representative of general rather than of individual conditions to which engines may be subjected, oil samples taken from cars of the same make and of the same locality were compounded. These compounded samples were then subjected to the following analysis.

ANALYSIS CARRIED OUT BY THE BUREAU OF STANDARDS

PART 1

Determine the percentage of dilution by the capillary-funnel method, the water to be separated and measured; these ingredients are to be given in percentage of volume. Then dilute a 10-gram sample with light naphtha to give a volume of 100 cc. Allow this to precipitate and filter. Record the precipitate as insoluble material. Treat the naphtha-insoluble material with benzol to obtain asphaltenes. Burn the remainder, which is known as benzol insoluble, at a low temperature, approximately 700 deg. cent. (1292 deg. fahr.) and record the loss as carbon.

The carbon losses will include combustible matter found in the oil, such as organic dust, lint and fibers. However, the percentages of the latter particles are ordinarily small as compared to the carbon from the oil. The incombustible residue is recorded as ash. In this are contained in oxidized form all the ingredients that become admixed with the oil during use, such as silica, sulphur, iron, and other metals.

PART 2

Subject 25 grams of the compounded sample to a thorough chemical examination. Burn this completely to ash. Dissolve this ash in hydrochloric acid, then precipitate the copper, tin and lead with hydrogen sulphide, and the iron oxide with ammonia. Filter the acid solution and burn the filter-paper. Dissolve this ash in a platinum dish in hydrofluoric acid containing a small percentage of sulphuric acid. Evaporate this solution to dryness and heat strongly. The acids and the silica that have been converted to silicon fluoride are volatilized and the loss in weight figured from the ash is reported as silica.

TABLE 2—DATA ON VARIOUS OILS USED

[illegible]

CAUSES OF WEAR AND CORROSION IN ENGINES

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DATA OBTAINED FROM THE 1925 SURVEY

The various determinations made in these analyses were compiled by the Bureau of Standards and are given in Table 1. In the first column of Table 1 the letters A to K indicate groups, each consisting of one make of car, there being in all 10 different makes of car. The sample numbers, C-1 to C-27, represent identification numbers given here for purposes of record only. Column 3 represents the number of samples taken from cars of the same make that were used to make up one compounded sample. The number of individual samples that were used to make up one compounded sample varied from 3 to 12, depending on the response and cooperation received from the service stations and on the suitability of the samples obtained for analysis. Column 4 represents the locality where the car from which the oil sample was taken was operated. The data in Column 5 show the period of time during which the car was run. In Column 6, the fuel that was used is given. In Column 7, the identification is given of the oil that was used. Particulars of the various oils used are given in Table 2.

The results obtained in the first part of the analysis, namely, the percentages of dilution, water, naphtha-insolubles, asphaltenes, carbon, and ash, are given in Columns 8 to 13 of Table 1, dilution and water being given in percentage of volume, while the other data are given in percentage of weight. The results obtained in the second part or the chemical analysis are given in Columns 14 to 22. It will be noted from Table 1 that the ash is given as obtained in the first part of the analysis and also as obtained in the second part or the chemical analysis when a 25-gram sample was burned before any other manipulations were carried out.

It will be noted further that Column 21 is marked Silica from Iron. This represents the total weight of silica that was computed as being present due to the average percentage of silica generally found in cast iron. The difference between the two represents the amount that must have come from road dust unless the castings and other parts were never thoroughly cleaned. Inasmuch as the silica in the average represents only 8.0 per cent of the ash, while the iron oxide in the average represents over 70.0 per cent, it follows that about 2.8 per cent of silica or 35.0 per cent of the total weight of silica found, may come from the cast iron.

The figures marked "weighted mean" as given at the foot of each group are arrived at through arithmetical calculation. The reasoning followed in this calculation is as follows: If a small number of samples are compounded, the results very likely will consist of either high or low values merely because a single sample in the compound represents extraordinary conditions. If a large number of samples are compounded, the influence of one odd sample naturally becomes proportionately less and, further, an unusual sample is more likely to be balanced by another sample representing opposite conditions. Therefore, the weighted mean for a compound made up from two groups, one consisting of 11 samples and the other of 3, is obtained by first multiplying the percentage of ingredients of the first group by 11 and those of the second by 3. The sum of the two products so obtained is then divided by the total number of samples in the compound, which would be 14 in this case.

The "grand mean" given at the foot of each column in Table 1 is determined for the entire number of samples in the same manner as the weighted mean was determined for each group of cars. Hence we may say that for 225 samples of oil representative of service con-

TABLE 3—AVERAGE VALUES OF 225 USED-OIL SAMPLES

	Analysis of Samples, Per Cent	Values Based on Ash as 100 Per Cent
Dilution.....	14.6000	.....
Insolubles.....	0.4840	.....
Asphaltenes.....	0.0640	.....
Carbon.....	0.2740	.....
Ash.....	0.1470	.....
Ash.....	0.1515	100.0
Iron oxide.....	0.1075	71.0
Copper oxide.....	0.0035	2.3
Tin oxide.....	0.0051	3.4
Lead oxide.....	0.0012	0.8
Metals.....	0.1178	77.5
Silica.....	0.0167	11.0
Silica from iron.....	0.0122	8.0
Other compounds.....	0.0169	11.2

ditions, as they are encountered from February to May, the figures given in Table 23 represent average values.

PATHOLOGY OF INTERNAL-COMBUSTION ENGINES

The medical profession reads the symptoms of various diseases from certain ingredients derived from the blood or from other substances taken from the human body. To read in a similar manner from the ingredients found in an oil certain indications as to what has taken place with regard to wear and corrosion in an engine that has been lubricated by the oil under consideration may be feasible. Inasmuch as the percentages of harmful ingredients found are necessarily very small, the analysis of the oil should be very accurate and conclusions be drawn with extreme care. Having available very accurate information from a fair number of samples, such as that given in Table 1, an attempt will be made to diagnose the various cases for wear and corrosion. To facilitate this work, we need to know the characteristics of the oil before it was contaminated. The physical characteristics of nearly all the oils that were used in the tests were recorded by the Bureau of Standards and are given in Table 2.

Of all the ingredients found in the oil, obviously the iron is of greatest importance inasmuch as this can be taken normally as a fair measure of the amount of wear and corrosion; or, in short, of the depreciation that has taken place in the engine. Some of the iron may have segregated out with other constituents of the sludge, but as all of the oil analyzed was in service for between only 500 and 1000 miles, the quantity that became segregated may be taken as small; it will also be a fairly proportional quantity for all samples obtained. Hence, the results should be at least qualitatively correct. Moreover, as the samples were taken in all cases from oil that was continually circulated, that particles of iron have become mixed with it from other causes than wear and corrosion is improbable.

CRITERION FOR TRACING SOME CAUSES OF CONTAMINATION BY INGREDIENTS FOUND IN THE ASH

In the analysis of the oil samples all the iron was reduced to iron oxide. This procedure makes it very difficult to determine whether the iron became mixed with the oil because of abrasion or of corrosion. To differentiate between wear and corrosion we shall have to rely on certain axiomatic relations noticeable through differences in percentages of the various ingredients found in the ash. The relations given below will be generally accepted.

- (1) Wear is a function of the mass of the silica, the viscosity, the mass of abraded metal particles, and the number of starts. Starting frequently involves rubbing on dry and partly corroded surfaces
- (2) Corrosion is a function of water, the sulphur content of the fuel, intermittent running, and time

If the iron oxide found is mainly the result of wear, it will very likely be accompanied by other ingredients, such as silica and non-ferrous metals. These latter ingredients constitute a certain percentage of the ash and, therefore, while helping to increase the total, they will keep the percentage of iron oxide in the ash low.

When corrosion takes place, iron oxide becomes mixed with the oil in addition to the iron resulting from wear. Such admixture of iron oxide should, therefore, necessarily increase the percentage of iron oxide found in the ash.

From this we derive a criterion on which we will depend to some extent in the individual diagnoses of the various oil samples, namely, that, if the percentage of iron oxide in the ash is found to be low, wear has been the predominating factor; while if this percentage is high, corrosion very likely has taken place. Extreme care must be taken in applying this criterion, inasmuch as no account is taken whether it is of the ingredients given in Column 22 of Table 1, marked "Other Compounds." These are the compounds that are present in the ash in some cases in as large percentages as silica. Further, wear tests can be run in a laboratory under controlled conditions with thoroughly clean engines in which the analysis of the oil will reveal a high percentage of iron in the ash in spite of the fact that wear has been the predominating factor while corrosion has been kept to the minimum. In extraordinary cases like this, our criterion perhaps would fail to apply. However, in a survey of this kind, one extreme is usually balanced by another through compounding, and in cases like this the criterion applies very well. This will be proved in somewhat greater detail in the latter part of this paper.

INFLUENCE OF VARIOUS FACTORS ON CONTAMINATION

The inter-relation of these and other factors can be studied best by taking the most important data given in Tables 1 and 3 and by arranging them as in Fig. 1. Each individual analysis of the various compounded samples is represented by a vertical line. The positions of these lines relative to one another along the axis of abscissas are determined by the total percentage of iron oxide found in the ash. Silica, ash, viscosity, temperature, and dilution are represented as ordinates. Having these factors plotted according to their respective scales, we can read their inter-relation conveniently.

We note, for instance, that, from the number of samples there represented, an approximate linear relation is discernible between iron oxide and ash. With regard to all other factors we note considerable irregularity. For this reason, each case must be considered individually, taking the percentage of iron oxide in the ash as a guide. To do this, Table 4 has been prepared in conjunction with Fig. 1. Samples in Table 4 can be conveniently identified with those in Fig. 1; hence the percentages of iron oxide, silica and other ingredients are not repeated there. However, for a more intimate study of their inter-relations, the silica and the non-ferrous metals are given as percentages of the ash. In the last column of Table 4 are given diagnoses such as may be read from the inter-

relation of the data corresponding to the respective samples.

In the diagnosis of the various compounded samples we find that fairly satisfactory relations exist between wear and silica and wear and viscosity, as well as between corrosion and water and corrosion and sulphur content of the fuel. The diagnosis necessarily consists of some mental manipulations in which accurate quantities can be absorbed by the mind only as very approximate values. This suggests the desirability that useful information be obtained from graphical representations. These will enable us to deal with accurate magnitudes and to visualize certain relations with greater precision. These advantages may outweigh the disadvantage that in each particular case we can consider only one factor which we expect will exert an influence on either wear or corrosion or its equivalent, namely, iron oxide and depreciation.

That the data now available, being obtained from only 225 cars, represent only little more than 0.001 per cent of the entire number of cars in use is also realized. The results must therefore be expected to be fragmentary. Far more reliable results could be given if analyses from about 2000 representative oil samples were available. Advancing this work to that state of perfection, if desired, would be possible through further co-operation with the Society. Through further elaboration the trend of the graphs may be expected to become more reliable, while at present it may still be considered by some as accidental.

GROUPING OF SAMPLES ACCORDING TO IRON OXIDE

Assuming that what has been said justified graphical representations, we shall first study the relation between silica and iron oxide. We have already stated that through compounding of various samples extreme conditions balance one another. This compounding has therefore been carried somewhat farther. In doing so the make of car has been ignored, inasmuch as sand in the oil and low viscosity within the limits of accuracy that we can expect will be equally harmful to any make of car. This approximation also applies to locality. We have further accepted as axiomatic that the percentage of iron oxide found is, in some measure, representative of the damage suffered by the engine. Therefore, that samples with about equal percentages of iron oxide should be averaged together appears logical. In doing this we obtain the grouping given in Table 5.

The fundamental data in Columns 2 to 4 and 7 to 9 are exactly the same as those given in Table 1. The total number of samples in each group is kept as nearly alike as possible, namely, 25. These new groups are designated *a* to *j*. The iron oxide, the silica and the ash given in Columns 13 to 15 represent weighted means of these ingredients for each group of about 25 samples. In determining weighted mean-values of the ingredients for the groups, calculations were carried out which are identical with those used in connection with the determining of the weighted means for Table 1. Examples of these calculations were given earlier in this paper.

RELATION BETWEEN SILICA AND IRON OXIDE

The relation of the iron-oxide and silica values given in Columns 13 and 14 of Table 5 is shown in Fig. 2. In this graphical representation the heavy inclined line indicates the silica that is computed as coming from the cast iron. The ordinates above the heavy line represent the percentage that must have come from road dust. They give, therefore, an illustration of the service that

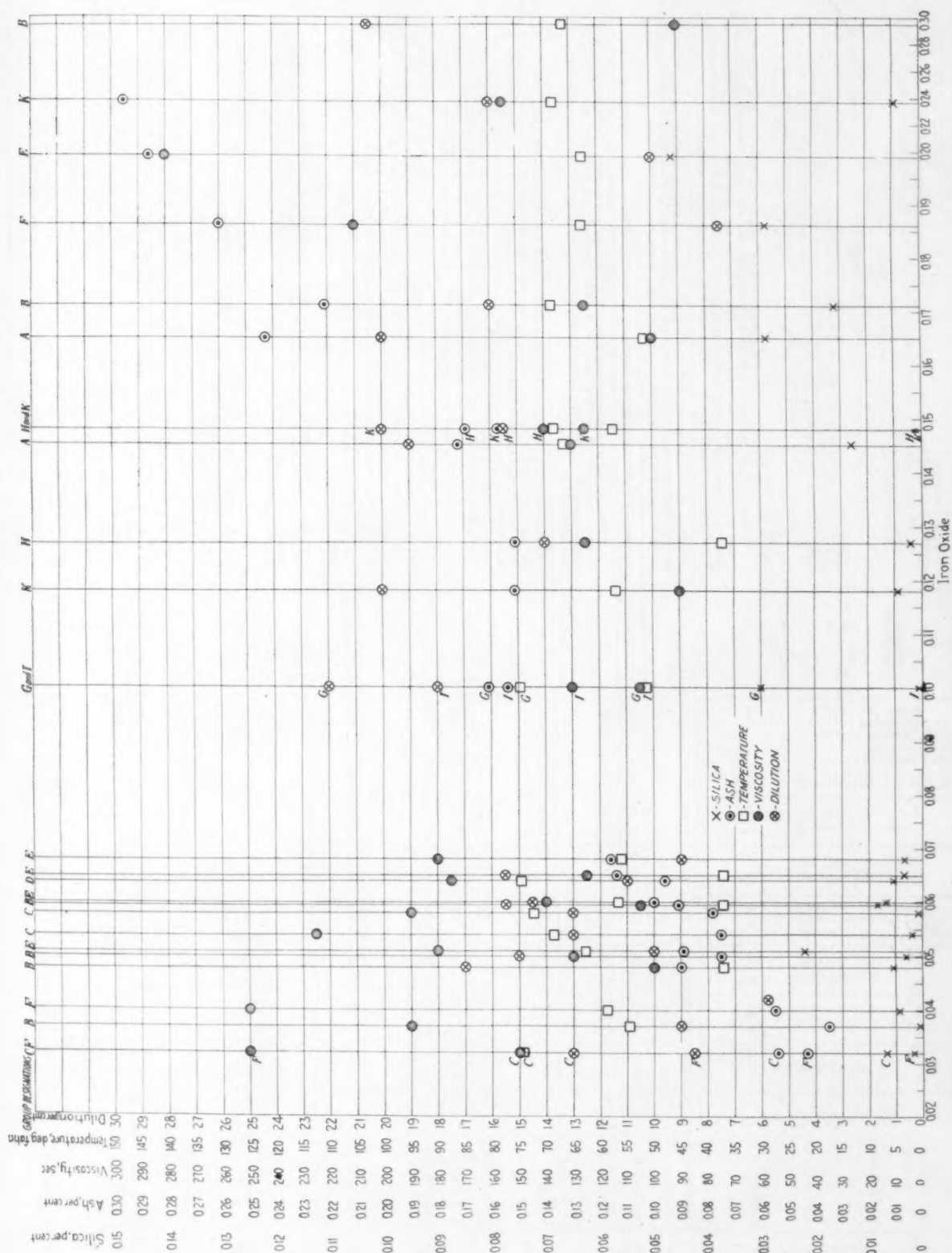


FIG. 1—IMPORTANT DATA FROM TABLES 1 AND 13. Each Individual Analysis of the Various Compounded Samples Is Represented by a Vertical Line. The Positions of These Lines Relative to One Another Along the Axis of Abscissas Are Determined by the Total Percentage of Iron Oxide Found in the Ash. Silica, Ash, Viscosity, Temperature, and Dilution Are Represented as Ordinates. The Factors Are Plotted According to Their Respective Scales, and Their Inter-Relation Is Apparent.

TABLE 4—DIAGNOSIS OF COMPOUNDED OIL-SAMPLES

Identification Number of Compounded Samples	Group Designating Make of Car	Number of Samples in Compound	Locality	Ingredients in Terms of Ash, Per Cent			Viscosity of Oil as Taken from Crankcase at 100 Deg. Fahr., Saybolt Sec.	Dilution by Volume, Per Cent	Water by Volume, Per Cent	Temperature Prevailing While Analyzed Samples of Oil Served as Lubricant, Deg. Fahr.	Average Distance for Which Analyzed Samples of Oil Served as Lubricant, Miles	Extra Equipment	Diagnoses
				Iron Oxide	Silica	Non-Ferrous Metals							
1	2	3	4	5	6	7	8	9	10	11	12	13	Case 1.—Low percentage of silica in the ash and the high viscosity suggest little wear. This is borne out by the very low total ash. Low dilution and absence of water indicate continuous running. Oil was taken from trucks apparently used steadily and well within their capacity in level country. The high percentage of iron oxide in the ash indicates some corrosion.
1	F	12	Detroit	74.4	3.95	9.30	250	8.5	0.00	Unknown	516		
1a	C	7	Oklahoma City	59.4	12.40	13.00	150	13.0	0.00	74.8	472	Air-cleaner and Oil Filter	
2	B	7	Oakland	100.5	1.43	1.50	190	9.0	0.20	54.7	639		Case 1a.—Air-cleaner and oil filter used; hence small percentage of ingredients. Conclusions as to wear and corrosion very uncertain as material collected in oil filter is left unconsidered. High silica ratio indicates that fine dust passes through air-cleaner and oil filter.
3	F	10	City of Washington	72.7	8.00	11.00	250	5.5	0.10	58.8	1,033		
4	B	4	Detroit	53.4	5.90	22.60	100	17.0	0.00	37.2	511		Case 2.—No conclusions drawn as percentage of iron oxide is higher than ash.
5	B	9	Minneapolis	66.7	4.00	5.30	130	15.0	0.40	44.2	465		Case 3.—This case is almost identical with Case 1. Applies to the same make of truck as Case 1. Note that a 100-per cent difference in silica accounts for a 25-per cent difference in the total iron oxide found. The very high viscosity prevented the silica from scratching; hence the quantity of it was less important.
6	E	3	Birmingham	57.4	24.70	5.60	180	10.0	0.00	62.7	455	Air-Cleaner	Case 4.—The percentage of iron oxide in the ash appears extremely low. This is partly because the percentage of other compounds in the ash was found high. In spite of this the percentage of iron oxide in the ash appears still low enough to suggest that corrosion was a small factor and wear predominated. The percentage of silica and the rather low viscosity corroborated this conclusion. These cars were used by experts for experimental purposes. The high percentage of non-ferrous metals found in the ash is explained through an extraordinary high percentage of lead found.
7	C	10	New Orleans	72.0	2.40	10.70	225	13.0	Trace	68.7	593	Air-Cleaner and Oil Filter	Case 5.—This may be considered a very satisfactory sample of oil. No comment is necessary.
8	C	8	Birmingham	74.4	0.90	5.10	190	13.0	Trace	72.4	489	Air-Cleaner and Oil Filter	Case 6.—Percentage of silica in ash unusually high. Air-cleaner most likely inoperative. Percentage of iron oxide in ash suggests absence of corrosion, in spite of the fact that a fuel which was usually high in sulphur was used. The high viscosity accounts for the fair results obtained for the large percentage of silica. Car was used by expert. The low dilution and the absence of water indicate warm engine, hence corrosion was low because of lack of condensation.
9	B	7	Detroit	65.6	9.23	8.80	105	15.5	Trace	37.2	486		Case 7.—Conclusions as to wear and corrosion impossible as material collected in oil filter is left unconsidered.
10	E	10	Tulsa	60.0	6.60	7.00	140	14.5	Trace	56.7	652		Case 8.—Unusually low silica, the high viscosity and the low percentage of non-ferrous metals indicate small wear. The high percentage of iron oxide found in the ash suggests corrosion. Fuel usually high in sulphur was used. Material collected by oil filter being left unconsidered makes conclusion hazardous.
11	D	4	Oklahoma City	66.7	5.62	9.40	175	11.0	Trace	74.8	506		Case 9.—Percentage of iron oxide in ash together with fairly high percentage of silica and non-ferrous metals found and the low viscosity, indicates that wear was obviously the predominating factor. Corrosion most likely was the minimum. The entire distance was covered by all cars in 2 days; hence corrosion could hardly have been a factor.
12	E	10	Detroit	57.0	11.00	14.00	125	15.5	0.25	37.2	652		Case 10.—This can be considered a very satisfactory sample of oil. Can be considered as good as Case 5 or any preceding it, inasmuch as the total iron oxide is only 20 per cent higher for 50 per cent greater mileage. The higher mileage also accounts for the higher silica and non-ferrous metals. The somewhat higher viscosity helped to keep abrasion low.

Case 11.—Mileage in both Case 9 and this about the same. Sample in this case has less silica and higher viscosity than Case 9; hence should have less wear. Total iron oxide and percentage of iron oxide in ash are higher in Case 11; hence corrosion must have been a stronger factor. This is likely as samples were in service for 2½ months while those in Case 9 served for 2 days only. Corrosion is of course, other things being the same, a function of time.

Case 12.—High silica and high non-ferrous metals together with low percentage of iron oxide in the ash suggest that wear was the predominating factor. The percentage of other compounds found in the ash was rather high, helping to account for the unusually low percentage of the iron oxide in the ash. Record sheets incomplete.

CAUSES OF WEAR AND CORROSION IN ENGINES

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TABLE 4—DIAGNOSIS OF COMPOUNDED OIL-SAMPLES (Concluded)

Identification Number of Compounded Samples	Group Designating Make of Car	Number of Samples in Compound	Locality	Ingredients Given in Terms of Ash, Per Cent			Viscosity of Oil as Taken from Crankcase at 100 Deg. Fahr., Saybolt Sec.	Dilution by Volume, Per Cent	Water by Volume, Per Cent	Temperature Prevailing While Analyzed Samples of Oil Returned as Lubricant, Deg. Fahr.	Average Distance for Which Analyzed Samples of Oil Returned as Lubricant, Miles	Extra Equipment	Diagnoses
				Iron Oxide	Silica	Non-Ferrous Metals							
1	2	3	4	5	6	7	8	9	10	11	12	13	
13	E	10	San Francisco	58.6	2.85	4.40	180	9.0	0.00	56.1	1,353		Case 13.—This can be considered a very satisfactory sample of oil, can be considered as good as Case 5 or any preceding it. The reason that the total iron in sample is 36 per cent higher than in Case 5 is because the mileage is nearly 200 per cent higher.
14	I	11	Detroit	65.0	0.00	7.70	130	18.0	0.60	51.4	700	Air-Cleaner	Case 14.—Air-cleaner accounts for absence of silica. High percentage of non-ferrous metals in ash indicates wear in spite of no silica. Such wear is probable as all cars were new; hence ridges and loose particles were taken off quickly.
14a	G	9	New Orleans	62.2	18.60	6.80	105	22.0	0.10	74.8	1,434		Case 14a.—Average percentage of iron oxide in ash, the high percentage of silica and the low viscosity suggest that wear was the predominating factor. Comparing this sample with Case 9, we find the same viscosity in both cases. In this case, the silica is 100 per cent higher than in Case 9, causing 60 per cent greater total iron oxide.
15	K	11	San Francisco	78.2	2.85	4.60	90	20.0	0.00	56.9	675		Case 15.—Low viscosity suggests undue wear. High dilution suggests frequent starting which usually involves frequent rubbing on dry and partly corroded surfaces. These two factors may account for the very high percentage of iron oxide in ash.
16	H	6	Detroit	84.1	1.32	2.60	125	14.0	Trace	37.2	851		Case 16.—Very low silica, low non-ferrous metals and fair viscosity suggest minimum abrasion. High percentage of iron oxide in ash suggests corrosion. Cause unknown.
17	A	6	Atlanta	84.5	7.56	3.30	130	19.0	0.80	66.4	587		Case 17.—High silica responsible for some abrasion. High percentage of iron oxide in ash suggests corrosion. High percentage of water likely cause of corrosion.
18	K	5	Birmingham	94.3	0.06	2.50	125	20.0	Not Given	68.2	423		Case 18.—Unusually low silica and low non-ferrous metals suggest very low wear. Unusually high percentage of iron oxide in ash suggests corrosion. Fuel usually high in sulphur might have been used, suggesting possibility of corrosion.
18a	H	11	Birmingham	87.6	0.65	1.15	140	15.5	0.00	57.2	695		Case 18a.—Unusually low silica and high percentage of iron oxide in ash suggest that corrosion was the predominating factor. Fuel usually high in sulphur was used; hence corrosion very likely.
19	A	11	Detroit	68.1	11.75	4.40	100	20.0	Trace	51.4	644		Case 19.—High silica, medium non-ferrous metals and poor viscosity suggest wear. High dilution indicates frequent starting and rubbing on dry and partly corroded surface. Vehicles were engaged in road building and hauling sand and gravel. This accounts for high total ash and iron oxide.
20	B	12	Birmingham	77.5	7.20	4.30	125	16.0	Trace	68.7	525		Case 20.—Medium silica, medium non-ferrous metals and fair viscosity suggest average abrasion. High iron oxide in ash suggests corrosion. Fuel, usually high in sulphur, was used suggesting possibility of corrosion.
21	F	10	San Francisco	71.5	11.0	7.00	210	7.5	Trace	63.0	775		Case 21.—High total iron as well as high percentage of iron in ash likely to be caused by abrasion. While viscosity is high, the 10 vehicles here under consideration are heavy-duty trucks pulling heavy trailers indicating high crankcase temperature; hence viscosity lower than given. Four of these trucks were hauling crushed stone, hence coarse silica caused abrasion in spite of good viscosity.
22	E	7	Birmingham	69.5	16.05	5.60	280	10.0	0.20	62.7	595		Case 22.—High viscosity together with fairly low non-ferrous metals suggests medium wear in spite of high silica. Silica may be fine and float in oil-film. High percentage of iron in ash suggests corrosion. Fuel usually high in sulphur was used.
23	K	5	Birmingham	80.4	1.56	4.40	155	16.0	0.20	68.0	465		Case 23.—Very high percentage of iron oxide in ash suggests corrosion. Low silica and fair viscosity suggests medium abrasion.
24	B	10	Oklahoma City	65.7	18.25	9.10	90	20.5	Trace	66.0	420		Case 24.—Very high silica and very low viscosity and high non-ferrous metals suggest much wear and are very likely responsible for the high total iron and ash. The high dilution suggests frequent starting and rubbing on dry and partly corroded surfaces.

TABLE 5—SAMPLES GROUPED ACCORDING TO PERCENTAGE OF IRON OXIDE

Groups Based on Iron-Oxide Values	Make of Vehicle	Number of Samples in Compound	Locality	Distance Covered as Lubricant, Miles	Total Number of Samples in One Group	Percentage of Ingredients in Compounded Samples taken from Table 1				Ingredients on Basis of Groups of Samples				Dilution				Viscosity of Diluted Oil at 100 Deg. Fahr., Saybolt Sec.	Product of Number of Samples Given in Column 19	Sum of One Group of Figures Given in Column 20 Divided by Figures in Column 6	Ingredients Calculated for 1000 Miles as Uniform Basis				
						Product of Number of Samples Given in Column 2 and Ingredients Given in Column 3 and Ingredients Given in Column 8				Product of Number of Samples Given in Column 3 and Ingredients Given in Column 8				Product of Number of Samples Given in Column 3 and Ingredients Given in Column 8							Product of Number of Samples Given in Column 3 and Viscosity				
						Iron Oxide	Silica	Ash	Product of Number of Samples Given in Column 3 and Ingredients Given in Column 8	Iron Oxide	Silica	Ash	Sum of One Group of Figures Given in Column 10 Divided by Figures in Column 6	Sum of One Group of Figures Given in Column 11 Divided by Figures in Column 6	Sum of One Group of Figures Given in Column 12 Divided by Figures in Column 6	Dilution Found in Samples	Product of Number of Samples Given in Column 16				Sum of One Group of Figures Given in Column 17 Divided by Figures in Column 6	Iron Oxide	Silica	Iron Oxide	Silica	Sum of One Group of Figures Given in Column 10 Divided by Figures in Column 5 Multiplied by 1000	Figures in Column 11 Divided by Figures in Column 6	Sum of One Group of Figures Given in Column 22 Divided by Figures in Column 6	Sum of One Group of Figures Given in Column 23 Divided by Figures in Column 6
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	
a	C	7	Oklahoma City	472	26	0.0320	0.0080	0.054	0.224	0.056	0.378				13.0	91.0		150	1,050		0.475	0.119			
	F	12	Detroit	516		0.0320	0.0030	0.043	0.384	0.036	0.516					8.5	102.0		250	3,000		0.745	0.070		
	B	7	Oakland	639		0.0370	0.0010	0.035	0.259	0.007	0.245					9.0	63.0		190	1,330		0.405	0.011		
b	F	10	City of Washington Detroit Minneapolis	1,033	23	0.0400	0.0060	0.055	0.400	0.060	0.550				5.5	55.0		250	2,500		0.388	0.038			
	B	4		0.0480		0.0072	0.030	0.192	0.029	0.360					17.0	68.0		100	400		0.376	0.057			
	B	9		0.0500		0.0050	0.075	0.450	0.045	0.675					15.0	135.0		130	1,170		0.965	0.017			
c	C	10	New Orleans Detroit Tulsa	593	27	0.0540	0.0040	0.075	0.540	0.040	0.750				13.0	130.0		225	2,250		0.910	0.037			
	B	7		0.0596		0.0108	0.031	0.417	0.076	0.637					15.5	108.5		105	735		0.830	0.155			
	E	10		0.0600		0.0090	0.100	0.600	0.090	1.000					14.5	145.0		140	1,400		0.920	0.138			
d	D	4	Oklahoma City Detroit San Francisco	506	24	0.0640	0.0080	0.096	0.256	0.032	0.384				383.5	383.5		175	700		2.690	0.361	0.1000	0.0134	
	E	10		0.0650		0.0060	0.114	0.650	0.080	1.140					11.0	44.0		105	945		0.503	0.083			
	E	10		0.0680		0.0060	0.116	0.680	0.060	1.160					15.5	155.0		180	1,800		1.000	0.092			
e	G	9	New Orleans Detroit	1,434	20	0.1000	0.0340	0.161	0.900	0.305	1.449				289.0	289.0		105	3,750		2.005	0.199	0.0840	0.0083	
	I	11		0.1000		0.0040	0.154	1.100	0.044	1.694					9.0	90.0		130	1,430		0.630	0.213			
															22.0	198.0		130	1,430		1.570	0.095			
f	K	11	San Francisco Detroit Atlanta	675	23	0.1180	0.0090	0.151	1.300	0.099	1.661				396.0	396.0		90	990		1.930	0.147			
	H	6		0.1270		0.0070	0.151	0.762	0.042	0.908					20.0	220.0		125	750		0.845	0.019			
	A	6		0.1452		0.0188	0.172	0.872	0.113	1.032					19.0	114.0		130	780		1.490	0.193			
g	K	5	Birmingham Detroit San Francisco	423	26	0.1480	0.0060	0.157	0.740	0.030	0.785				418.0	418.0		125	625		4.315	0.389	0.1880	0.0169	
	A	11		0.1652		0.0352	0.243	1.820	0.388	2.673					20.0	220.0		100	1,100		1.750	0.071			
	F	10		0.1860		0.0360	0.260	1.890	0.360	2.600					7.5	75.0		200	2,000		2.830	0.601			
h	B	10	Oklahoma City	420	10	0.2950	0.0340	0.449	2.950	0.940	4.490				395.0	395.0		90	900		6.980	1.140	0.2680	0.0140	
	B	3		0.0510		0.0240	0.089	0.153	0.072	0.267					20.5	205.0		125	625		1.750	0.071			
	C	8		0.0580		0.0030	0.078	0.465	0.024	0.624					10.0	30.0		180	540		0.336	0.158			
i	B	12	Birmingham Birmingham Birmingham	525	23	0.1712	0.0228	0.221	2.060	0.274	2.652				326.0	326.0		125	1,520		3.920	0.522			
															16.0	192.0		90	1,020		0.952	0.019			
																14.2	326.0		155	3,560		5.208	0.729	0.2260	0.0317
	H	11	Birmingham Birmingham Birmingham	695	23	0.1480	0.0070	0.169	1.630	0.077	1.839				170.3	170.3		140	1,540		2.350	0.111			
	E	7		0.1990		0.0540	0.286	1.390	0.378	2.002					15.5	170.3		140	1,540		2.340	0.635			
	K	5		0.2370		0.0140	0.295	1.185	0.070	1.475					16.0	80.0		155	775		2.550	0.150			
					23	4.205	0.525	5.336	0.1830	0.0228	0.2320				320.3	320.3		186	4,275		7.240	0.896	0.3150	0.0380	

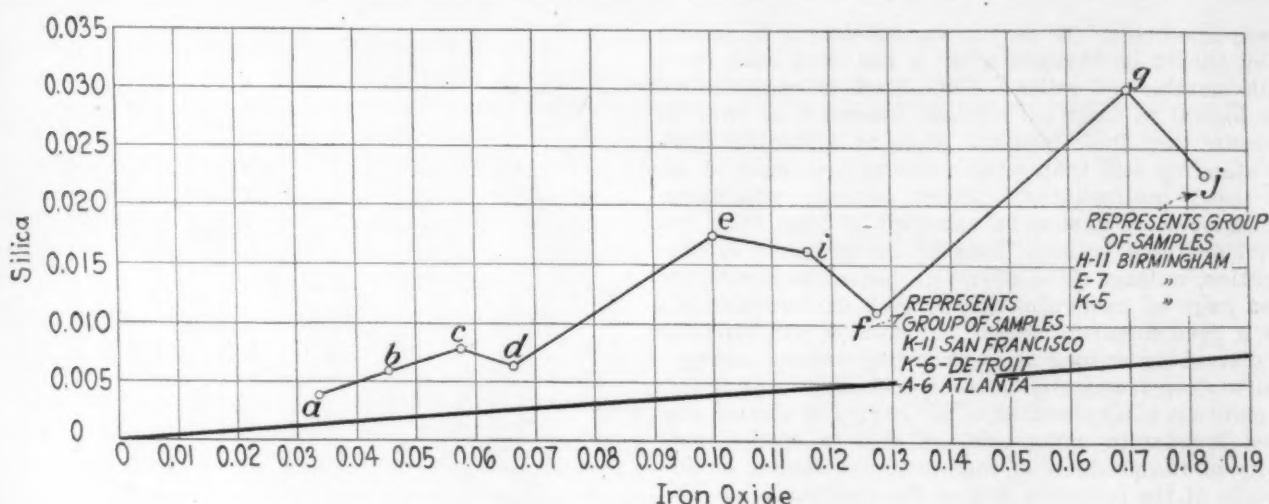


FIG. 2—RELATION OF IRON-OXIDE AND SILICA VALUES IN COLUMNS 13 AND 14 OF TABLE 5

The Heavy Inclined Line Indicates the Silica That Is Computed as Coming from the Cast Iron. The Ordinates above the Heavy Line Represent the Percentage That Must Have Come from Road Dust. The Chart Illustrates the Service That an Air-Cleaner Could Render

an air-cleaner could render. For reasons previously stated, some of the silica is not unlikely the remains of core-sand, from sand-blasting and from other substances that were not removed from the castings and the machined parts during the manufacturing processes.

Each point on the broken line represents one group of about 25 samples. The letters on the broken line will serve to identify the points with the various groups of Table 5. A fair trend is discernible from the broken line. However, points *f* and *j*, as will be noted, do not come very well in line with the others. For this reason, the constituent compounds of the group have been marked so that they can be identified with the diagnosis given for the same compounds in Table 4. In all samples constituting points *f* and *j*, the percentage of iron oxide in the ash will be found to be very high. Such high ratios we accepted in the diagnosis as indicating that corrosion took place or that wear was caused by either very low viscosity or frequent rubbing of dry and partly corroded surfaces, a condition frequently encountered in starting. As these latter conditions, although responsible for much of the iron oxide found, are entirely independent of the silica, we must, of course, expect that they will not come in line in a curve designed to reveal the relation of silica to iron oxide.

EFFECT OF MILEAGE ON SILICA-IRON OXIDE RELATION

We observed several times in our diagnosis that the mileage run while the oil was in service appeared to

exert an influence on the total percentage of ingredients found. Moreover, in an earlier part of this paper, we pointed out that the survey was carried out with the expectation that information might be obtained which would help engineers in formulating conclusions as to how frequently crankcase oil should be changed. This problem resolves itself into the question whether a definite stage in contamination can be found after which the oil is likely to do as much harm to the engine as to balance the cost of new oil. Inasmuch as, without frequent chemical analyses, an owner does not know how rapidly contamination increases, to learn whether a relation exists between contamination and mileage would be desirable.

To consider the influence of mileage, Columns 22 to 25 were added to Table 5. In these are given values of iron oxide and silica that correspond to those given in Columns 13 and 14, except that they are divided by the mileage and multiplied by 1000. Hence, the values in Columns 24 and 25 should represent iron oxide and silica, the mileage being given as adequate consideration as seems feasible under the circumstances. A graphical representation of these values is given in Fig. 3. The fluctuations in Fig. 3 are somewhat less than those in Fig. 2, indicating that mileage exerts some influence. As may be expected, points *f* and *j* again do not come exactly in line with the others, for the same reasons, of course, as previously given.

In an earlier part of this paper we pointed out that a

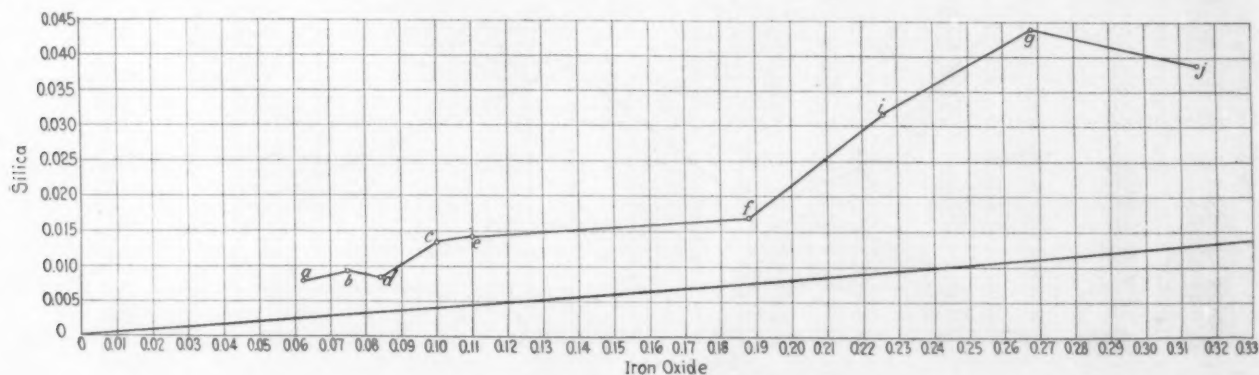


FIG. 3—GRAPHICAL REPRESENTATION OF IRON-OXIDE AND SILICA VALUES

These Are Taken from Columns 24 and 25 of Table 5, Mileage Being Given as Adequate Consideration as Seems Feasible. As Will Be Noted the Fluctuations Are Somewhat Less Than Those in Fig. 2, Indicating That Mileage Exerts Some Influence

common practice on the part of car-builders is to specify that oil should be changed after it has been used for a certain number of miles. This kind of specification seems logical to most car-owners, inasmuch as they do not realize that their cars are likely to depreciate more while standing still than when running and, most of all, when used intermittently under adverse conditions. While car-owners cannot be expected to have their engine oil analyzed to keep track of the progress of contamination, mileage alone obviously cannot be considered a good gage of contamination so long as corrosion remains a predominating factor. Corrosion will continue to be disturbing so long as engine temperatures are permitted to drop frequently to the freezing-point or lower. The condition is accentuated if the engine is started and stopped frequently when cold, as then a considerable quantity of the products of combustion condenses on the cold walls of the cylinders and of the crankcase.

With regard to the relation between viscosity and mileage, this condition is analogous inasmuch as viscosity is, aside from temperature, controlled entirely by dilution and, after some 150 miles of running, this is not as much a function of mileage as of other factors such as cooling-water and oil temperatures, the fuel, the mixture-ratio, and the ventilation of the crankcase. The Society has for several years made numerous successful efforts to have papers presented which call attention to the dangers of low engine-temperatures. For the reasons given, reference has been made to mileage only in cases when wear predominated and then only in a very casual way.

EFFECT OF VISCOSITY ON ACCUMULATION OF IRON OXIDE

As the viscosity decreases, the oil-film thickness also becomes less. This is very apt to be the cause of exceptional wear, if not actual seizure, particularly under heavy-duty service or when otherwise the oil temperature rises. Inasmuch as in this investigation the viscosity of the contaminated oil was not determined in the laboratory, this had to be obtained from certain available information. To do this the viscosity of the new oil as given in Table 2 had to be taken, together with the

* See THE JOURNAL, February, 1926, p. 164.

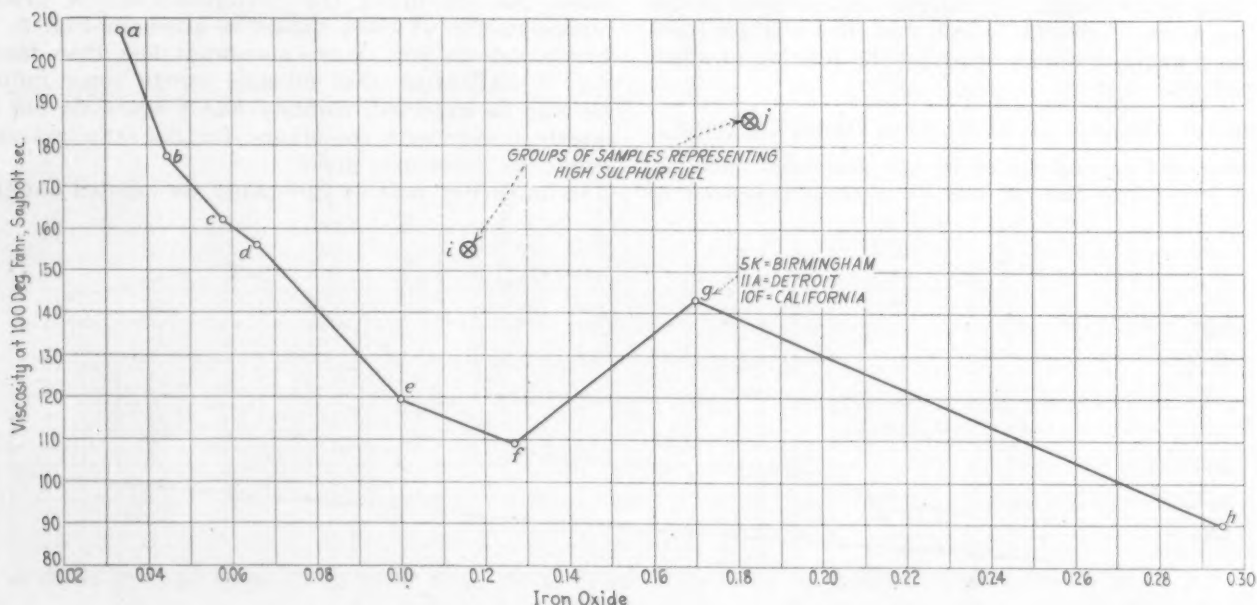


FIG. 4—RELATION BETWEEN THE VISCOSITIES GIVEN IN TABLE 5 AND THE IRON OXIDE CORRESPONDING TO THE VARIOUS GROUPS FOLLOWING THE TREND OF POINTS *a* TO *h*. IT IS EVIDENT THAT, IF A CONTINUOUS CURVE WERE DRAWN, THIS WOULD SHOW A DECIDED FLATTENING-OUT BELOW 100 SAYBOLT SEC., INDICATING THAT AT APPROXIMATELY SUCH VISCOSITY THE IRON OXIDE SUDDENLY INCREASES

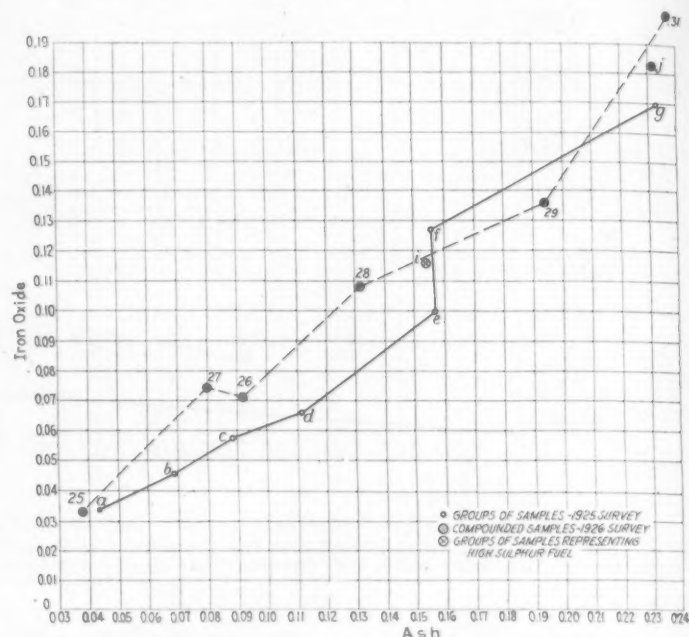


FIG. 5—RELATION BETWEEN IRON OXIDE AND ASH. IT WILL BE NOTED FROM THE HEAVY LINE THAT POINTS *a*, *b*, *c*, *d*, AND *e* FORM AGAIN, AS IN FIG. 2, 3 AND 4, ONE CONTINUOUS LINE. THESE POINTS ARE CHARACTERISTIC OF CONDITIONS IN WHICH WEAR PREDOMINATED

dilution given in Table 4. With these data and by referring to Fig. 1 of the paper on A Suggested Remedy for Crankcase-Oil Dilution*, by R. E. Wilson and R. E. Wilkin, the viscosity of the diluted oil was determined and given for the various compounded samples in Column 8 of Table 4.

To present graphically the relation existing between viscosity and iron oxide, some further compounding very similar to that in the case of the data represented in Fig. 1 was carried out. In Columns 19 and 20 of Table 5 are given the basic figures that have been compounded, and Column 21 of Table 5 gives the weighted viscosities in Saybolt seconds at 100 deg. Fahr. for the various groups. The relation between the viscosities so obtained and the iron oxide corresponding to the various groups is represented in Fig. 4. To note the very decided in-

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TABLE 6—ANALYSIS OF THE 1926 OIL SAMPLES

Groups Designating Make of Car	Identification Number	Number of Samples in Compound	Supplied Data			Examination of Used Oil			Examination of Fuel			
			Locality	Date Samples Were Received	Extra Equipment	Proportion of Used Oil by Volume, Per Cent		Proportion of Used Oil by Weight, Per Cent	Specific Gravity	90 Per Cent Point, Deg. Cent.	Corrosion	Sulphur
						Dilution	Water					
1	2	3	4	5	6	7	8	9	10	11	12	13
A	C-19	4	Detroit	3-8-26	No data	20.0	0.9	0.052	No	gasoline		
	C-29 ¹	6	Atlanta	3-18-26	None	18.5	1.7	0.222	0.745	194	None	0.070
	C-29 ²	3	Atlanta	3-18-26	Radiator shutter	19.0	2.2	0.252	0.745	194	None	0.070
	29-E	1	Atlanta	3-18-26	None	44.0	0.1	0.268	0.745	194	None	0.070
	29-H	1	Atlanta	3-18-26	Radiator shutter	12.0	Trace	0.32	0.745	194	None	0.070
	C-31	8	Dallas	3-18-26	None	14.5	0.4	0.150	0.741	192	OK	0.035
	31-I	1	Dallas	3-18-26	Manifold heater	8.0	0.2	0.176	0.741	192	OK	0.035
	C-34	5	Detroit	3-27-26	None	18.5	0.4	0.062	No	gasoline		
	34-E	1	Detroit	3-27-26	None	21.5	0.1	0.063	No	gasoline		
	C-36	7	San Francisco	4-3-26	None	7.5	2.4	0.150	0.747	189	OK	0.049
	36-A	1	San Francisco	4-3-26	Oil filter	9.5	Trace	0.409	0.747	189	OK	0.049
B	C-1	10	Birmingham	1-29-26	None	24.0	3.2	0.339	0.767	199	OK	0.270
	1-C	1	Birmingham	1-29-26	Manifold heater	16.5	0.5	0.216	0.767	199	OK	0.270
	C-1	10	Detroit	2-4-26	None	19.0	0.5	0.121	0.745	198	OK	0.027
	4-E	1	Detroit	2-4-26	None	17.0	0.6	0.093	0.745	198	OK	0.027
	C-20	9	Dallas	3-10-26	None	17.5	0.5	0.112	0.743	197	None	0.035
	20-E	1	Dallas	3-10-26	None	13.0	0.1	0.150	0.743	197	None	0.035
	C-28	10	Oakland	3-18-26	None	10.5	0.5	0.084	0.749	174	OK	0.031
	28-E	1	Oakland	3-18-26	None	7.0	Trace	0.052	0.749	174	OK	0.031
	C-39	10	City of Washington	4-3-26	None	16.5	0.2	0.213	0.771	198	OK	0.116
	39-E	1	City of Washington	4-3-26	Manifold heater	18.0	0.4	0.176	0.771	198	OK	0.116
	C-45 ¹	7	Minneapolis	4-19-26	None	18.0	6.5	0.096	0.733	189	OK	0.027
	C-45 ²	3	Minneapolis	4-19-26	Hood cover	16.0	10.0	0.150	0.733	189	OK	0.027
	45-D	1	Minneapolis	4-19-26	Radiator shutter	17.0	8.4	0.057	0.733	189	OK	0.027
C	C-3 ¹	7	Oklahoma City	2-3-26	No data	14.5	0.8	0.092	No	gasoline		
	C-3 ²	3	Oklahoma City	2-3-26	No data	11.5	0.9	0.161	No	gasoline		
	C-12	6	San Francisco	2-23-26	Oil filter	9.0	0.2	0.014	.....	188	OK	0.037
	12-E	1	San Francisco	2-23-26	Thermostat	10.5	0.5	0.040	.....	188	OK	0.037
	12-C	1	San Francisco	2-23-26	None	6.0	Trace	0.020	.....	188	OK	0.037
	12-H	1	San Francisco	2-23-26	None	3.5	Trace	0.040	.....	188	OK	0.037
	12-J	1	San Francisco	2-23-26	None	6.0	0.3	0.040	.....	188	OK	0.037
	12-K	1	San Francisco	2-23-26	None	6.0	Trace	0.040	.....	188	OK	0.037
	C-16	7	Minneapolis	3-1-26	Oil filter	9.5	1.7	0.055	0.735	195	OK	0.043
	16-C	1	Minneapolis	3-1-26	Thermostat	7.5	0.4	0.054	0.735	195	OK	0.043
	16-F	1	Minneapolis	3-1-26	None	9.0	5.0	0.174	0.735	195	OK	0.043
	16-H	1	Minneapolis	3-1-26	None	8.5	0.5	0.082	0.735	195	OK	0.043
	16-I	1	Minneapolis	3-1-26	Radiator shutter	7.0	0.6	0.176	0.735	195	OK	0.043
	C-22	7	Detroit	3-12-26	Oil Filter	13.5	3.7	0.107	0.735	192	OK	0.037
	22-B	1	Detroit	3-12-26	Thermostat	14.0	0.2	0.186	0.735	192	OK	0.037
	C-30 ¹	5	Dallas	3-18-26	Oil filter	11.0	Trace	0.043	0.743	...	OK	0.035
	C-30 ²	4	Dallas	3-18-26	Thermostat	9.0	0.2	0.046	0.743	...	OK	0.035
	30-E	1	Dallas	3-18-26	Radiator shutter	34.0	Trace	0.223	0.743	...	OK	0.035
E	C-8	10	Detroit	2-15-26	None	21.5	0.5	0.102	0.743	200	OK	0.022
	8-E	1	Detroit	2-15-26	None	19.5	0.4	0.074	0.743	200	OK	0.022
	C-9	7	Birmingham	2-15-26	None	16.0	0.6	0.205	0.749	197	OK	0.227
	9-G	1	Birmingham	2-15-26	Radiator shutter	14.0	0.1	0.169	0.749	197	OK	0.227
	9-C	1	Birmingham	2-15-26	Air cleaner	12.0	Trace	0.079	0.749	197	OK	0.227
	9-I	1	Birmingham	2-15-26	Radiator shutter	8.5	0.4	0.097	0.749	197	OK	0.227
	C-18 ¹	3	Minneapolis	3-2-26	Manifold heater	17.5	0.5	0.047	0.733	186	OK	0.032
	C-18 ²	4	Minneapolis	3-2-26	Rectifier	10.5	3.5	0.018	0.733	186	OK	0.032
	C-18 ³	4	Minneapolis	3-2-26	Radiator shutter	11.0	1.8	0.019	0.733	186	OK	0.032
	C-23	10	Dallas	3-13-26	Manifold heater	18.5	0.7	0.176	0.741	197	OK	0.038
	23-E	1	Dallas	3-13-26	None	11.0	Trace	0.064	0.741	197	OK	0.038
	C-33	9	Atlanta	3-20-26	None	11.5	Trace	0.126	0.751	193	OK	0.055
	33-E	1	Atlanta	3-20-26	None	9.0	Trace	0.068	0.751	193	OK	0.055
	C-37 ¹	4	Tulsa	4-3-26	None	15.0	1.2	0.144	0.731	177	OK	0.018
	C-37 ²	3	Tulsa	4-3-26	No data	14.5	2.0	0.104	0.731	177	OK	0.018
	37-I	1	Tulsa	4-3-26	No data	16.0	1.8	0.170	0.731	177	OK	0.018
	C-44	7	Kansas City	4-17-26	None	34.0	0.9	0.108	0.743	200	OK	0.031
	44-C	1	Kansas City	4-17-26	Manifold heater	33.5	0.5	0.184	0.743	200	OK	0.031
	44-D	1	Kansas City	4-17-26	Radiator shutter	29.0	1.0	0.172	0.743	200	OK	0.031
	44-E	1	Kansas City	4-17-26	None	32.5	0.8	0.062	0.743	200	OK	0.031
	44-J	1	Kansas City	4-17-26	Manifold heater	28.5	0.5	0.153	0.743	200	OK	0.031
F	C-2	9	Birmingham	2-3-26	No data	18.0	Trace	0.256	No	gasoline		
	7-A	1	New Orleans	2-15-26	None	19.0	0.3	0.479	0.757	191	OK	0.065
	7-B	1	New Orleans	2-15-26	None	13.0	Trace	0.144	0.757	191	OK	0.065
	7-C	1	New Orleans	2-15-26	None	15.0	Trace	0.136	0.757	191	OK	0.065
	C-10	9	Tulsa	2-18-26	Radiator shutter	10.0	0.7	0.094	0.741	198	OK	0.005
	10-H	1	Tulsa	2-18-26	None	9.0	Trace	0.250	0.741	198	OK	0.005
	10-J	1	Tulsa	2-18-26	None	8.0	Trace	0.056	0.741	198	OK	0.005
	C-24	10	Detroit	3-15-26	None	11.5	8.2	0.092	0.747	199	OK	0.032
	24-E	1	Detroit	3-15-26	None	9.0	Trace	0.031	0.747	199	OK	0.032
	C-40	8	St. Paul	4-12-26	None	12.0	1.6	0.104	0.728	163	OK	0.018
	40-E	1	St. Paul	4-12-26	None	20.0	Trace	0.023	0.728	163	OK	0.018

crease of iron oxide with the falling off of viscosity is rather interesting.

Following the trend of points *a* to *h*, it is evident that, if a continuous curve were drawn, this would show a decided flattening-out below 100 Saybolt sec., indicating that at viscosities of approximately 100 Saybolt sec. the iron oxide suddenly increases. This might be expected because of the possibility that the oil-film might permit metallic contact. Point *g* is rather badly out of line. For this to be in line, the iron oxide should be about one-half of that found. The reason for this divergence is that 21 samples out of 26 constituting Group *g* were

taken from heavy-duty trucks engaged in road building. A large number of these trucks hauled crushed stone. Under these circumstances we must expect that coarse silica will cause unusual wear in spite of high viscosity. Moreover, in heavy-duty vehicles the oil temperature is very likely to be very high. This would reduce the viscosity for the samples of point *g* to below the value given in Table 5. However, the temperature of the oil was not recorded; therefore, the foregoing explanation is about the best that can be given. Points corresponding to Groups *i* and *j* were not taken into the graph. The samples constituting these groups were taken from cars

TABLE 6—ANALYSIS OF THE 1926 OIL SAMPLES—(Concluded)

Groups Designating Make of Car	Identification Number ¹	Number of Samples in Compound	Supplied Data			Examination of Used Oil			Examination of Fuel			
			Locality	Date Samples Were Received	Extra Equipment	Proportion of Used Oil by Volume, Per Cent		Proportion of Used Oil by Weight, Per Cent	Specific Gravity	90 Per Cent Point, Deg. Cent.	Corrosion	Sulphur
						Dilution	Water					
1	2	3	4	5	6	7	8	9	10	11	12	13
H	C-11	10	Dallas	2-20-26	Rectifier	8.0	Trace	0.285	0.743	199	OK	0.032
	11-E	1	Dallas	2-20-26	Rectifier	8.0	Trace	0.177	0.743	199	OK	0.032
	C-15	10	Detroit	3-1-26	Rectifier	12.0	Trace	0.191	0.743	200	OK	0.061
	15-C	1	Detroit	3-1-26	Thermostat	12.5	Trace	0.066	0.743	200	OK	0.061
	C-17	10	Kansas City	3-2-26	Radiator shutter	14.5	0.8	0.113	.....	199	OK	0.023
	17-E	1	Kansas City	3-2-26	Rectifier	21.0	Trace	0.215	0.743	199	OK	0.023
	C-32	9	San Francisco	3-18-26	Hood cover	6.5	Trace	0.099	0.747	178	OK	0.035
	32-E	1	San Francisco	3-18-26	Rectifier	6.0	Trace	0.104	0.747	178	OK	0.035
	C-41	9	Birmingham	4-14-26	Thermostat	10.0	0.4	0.206	No gasoline			
	41-E	1	Birmingham	4-14-26	Rectifier	13.0	Trace	0.136	No gasoline			
	C-42	3	City of Washington	4-15-26	Thermostat	15.0	Trace	0.224	No gasoline			
	42-B	1	City of Washington	4-15-26	Radiator shutter	9.5	Trace	0.203	No gasoline			
					Rectifier							
					Thermostat							
J	5-A	1	Baltimore	2- 9-26	Air cleaner	8.0	0.5	0.113	0.755	160	OK	0.057 ^c
	5-B	1	Baltimore	2- 9-26	None	7.0	1.2	0.074	0.755	160	OK	0.057 ^c
	5-C	1	Baltimore	2- 9-26	Rectifier	16.5	4.7	0.266	0.755	160	OK	0.057 ^c
	C-13	10	Portland, Ore.	2-24-26	None	14.5	0.8	0.163	.....	186	OK	0.040
	13-E	1	Portland, Ore.	2-24-26	None	12.0	0.2	0.066	.....	186	OK	0.040
	C-26 ¹	4	Boston	3-15-26	Radiator shutter	16.5	Trace	0.047	0.753	190	OK	0.041
	C-26 ²	2	Boston	3-15-26	None	19.5	0.2	0.098	0.753	190	OK	0.041
	26-E	1	Boston	3-15-26	None	21.0	Trace	0.074	0.753	190	OK	0.041
	C-35 ¹	4	Denver	3-31-26	Rectifier	30.5	Trace	0.086	0.749	200	OK	0.029
	C-35 ²	4	Denver	3-31-26	Radiator shutter	34.5	0.1	0.113	0.749	200	OK	0.029
	35-F	1	Denver	3-31-26	Rectifier	18.0	Trace	0.056	0.749	200	OK	0.029
	35-K	1	Denver	3-31-26	Rectifier	26.0	Trace	0.283	0.749	200	OK	0.029
	C-43	10	San Francisco	4-15-26	Radiator shutter	10.5	Trace	0.069	No gasoline			
	43-E	1	San Francisco	4-15-26	Hood cover	10.5	Trace	0.035	No gasoline			
K	C-6	7	San Francisco	2-11-26	None	14.5	0.8	0.043	0.745	180	OK	0.036
	6-E	1	San Francisco	2-11-26	Oil filter	11.0	0.1	0.013	0.745	180	OK	0.036
	6-A	1	San Francisco	2-11-26	Oil filter	14.0	7.0	0.120	0.745	180	OK	0.036
	6-I	1	San Francisco	2-11-26	Oil filter	7.5	0.6	0.004	0.745	180	OK	0.036
	6-K	1	San Francisco	2-11-26	Oil filter	10.0	0.4	0.013	0.745	180	OK	0.036
	C-14	8	Tulsa	2-27-26	None	28.5	2.7	0.109	0.739	202	OK	0.015
	14-E	1	Tulsa	2-27-26	Oil filter	45.0	2.1	0.052	0.739	202	OK	0.015
	14-J	1	Tulsa	2-27-26	Oil filter	26.5	1.0	0.298	0.739	202	OK	0.015
	C-21 ¹	4	Birmingham	3-10-26	Oil filter	4.5	0.4	0.077	0.753	197	OK	0.165 ^a
	C-21 ²	4	Birmingham	3-10-26	Radiator shutter	14.5	0.7	0.364	0.753	197	OK	0.165 ^a
	21-E	1	Birmingham	3-10-26	None	23.0	2.8	0.070	0.753	197	OK	0.165 ^a
	21-F	1	Birmingham	3-10-26	Radiator shutter	13.5	1.3	0.240	0.753	197	OK	0.165 ^a
	C-25 ¹	3	Detroit	3-15-26	Radiator shutter	13.0	6.8	0.083	0.743	194	OK	0.043
	C-25 ²	5	Detroit	3-15-26	None	19.0	6.0	0.124	0.743	194	OK	0.043
	25-A	1	Detroit	3-15-26	Oil filter	7.0	Trace	0.092	0.743	194	OK	0.043
	25-B	1	Detroit	3-15-26	Oil filter	16.5	3.7	0.102	0.743	194	OK	0.043
	C-27 ¹	7	Atlanta	3-18-26	None	20.5	5.2	0.234	0.745	197	OK	0.043
	C-27 ²	4	Atlanta	3-18-26	Oil filter	18.5	0.8	0.092	0.745	197	OK	0.043
	27-K	1	Atlanta	3-18-26	None	13.0	1.3	0.080	0.745	197	OK	0.043
	C-38	9	New Orleans	4- 3-26	None	26.0	2.3	0.160	0.746	193	OK	0.049
	38-B	1	New Orleans	4- 3-26	Manifold heater	9.5	0.8	0.188	0.746	193	OK	0.049
	38-E	1	New Orleans	4- 3-26	None	19.5	0.5	0.145	0.746	193	OK	0.049

¹ In this column the letter C preceding a number indicates a composite sample and the superior figures, the order of the composite samples made from a given box.

^a Benzol blend.

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TABLE 7—CHEMICAL ANALYSIS OF ASH FROM 1926 OIL SAMPLES

Group Designating Make of Car	Number of Samples in Compound	Composite Number ^a	Proportion of Used Oil by Weight, Per Cent								
			Ash	Iron Oxide	Copper Oxide	Tin Oxide	Lead Oxide	Metals	Silica	Silica from Iron	Other Compounds by Difference
1	2	3	4	5	6	7	8	9	10	11	12
B	10	C-1	0.311	0.276	0.008	0.005	^d	0.289	0.018	0.007	0.004
E	7	C-9	0.194	0.136	0.003	0.005	0.003	0.147	0.019	0.014	0.028
H	10	C-11	0.287	0.164	0.012	0.005	^d	0.181	0.011	0.004	0.095
K	4	C-21 ¹	0.080	0.074	0.001	0.001	^d	0.076	0.003	0.000	0.001
F	10	C-24	0.092	0.071	0.002	0.007	^d	0.080	0.014	0.011	0.002
K	5	C-25 ²	0.132	0.108	0.006	0.004	0.003	0.121	0.004	0.000	0.007
K	7	C-27 ¹	0.254	0.210	0.003	0.002	0.005	0.220	0.008	0.000	0.026
A	3	C-29 ²	0.237	0.200	0.008	0.005	^d	0.213	0.012	0.004	0.012
C	4	C-30 ²	0.038	0.033	^d	0.001	^d	0.034	0.004	0.003	0.000

^a The superior figures designate the order of the composite samples made from one group.^d Not detected.

using fuel that usually contains a very high percentage of sulphur. Considerable iron oxide may therefore be expected to have come from corrosion, causing the points to fall out of line.

In Fig. 5 are shown several graphs pertaining to the relation between iron oxide and ash. That points *a*, *b*, *c*, *d*, and *e* form again, as in Figs. 2, 3 and 4, one continuous line will be noted from the heavy line. These points are characteristic of conditions in which wear predominated. Point *f* falls out of line probably because of the very low viscosity that the samples revealed. Points *g*, *i* and *j* again fall out of line for the same reasons that were given in connection with Fig. 4.

DATA OBTAINED FROM THE 1926 SURVEY

The analyses and the interpretations so far presented pertained entirely to samples that were collected in the spring of 1925. The original data of this 1925 survey as given in Table 1 were first discussed in a preliminary way at a meeting of the Research Committee, held in October, 1925. At that time the decision was reached that arrangements should be made for the collection of samples which would be more representative of winter conditions than the samples collected in 1925. Further, it was agreed that in the analysis of these winter samples attention should be directed mainly to dilution, water and ash. Because of the anticipation that iron oxide would constitute a fixed percentage of the total ash, the expectation was that the analyses would be fairly complete without making a large number of chemical determinations of ingredients, such as metals and silica. A small number of such determinations were to be made from a few specially selected compounded samples.

Following this meeting arrangements were made at once with the same passenger-car and motor-truck builders and service stations that participated in the 1925 survey, and samples of contaminated oil representative of service conditions of the first 2 months of the year were collected and sent, like all the 1925 samples, to the Bureau of Standards for analysis. The samples arrived later than was expected and, therefore, the data given as furnished by the Bureau of Standards in Table 6 were not available until the interpretation of the 1925 data was very nearly completed.

That part of the 1926 data that can be amalgamated readily with the 1925 data is given in Table 7, as re-

ceived from the Bureau of Standards. In the interpretation of this we shall proceed in a very similar manner to that followed in the earlier part of this paper.

DIAGNOSIS OF SOME 1926 SAMPLES

Table 8 was prepared to facilitate the diagnosing of the new compounded samples, and it corresponds to Table 4 of the former investigation. In all cases except Group No. 30 the percentage of iron oxide found in the ash was rather high. According to a criterion frequently used earlier in the paper, high percentages of iron oxide in the ash suggest that iron oxide has accumulated because of corrosion rather than because of wear. The preponderance of the high percentages of the iron oxide in the ash, in the samples under consideration, furnishes an opportunity for checking either the correctness or the shortcoming of this criterion. As evidence in favor of its correctness we note at once that relatively large percentages of water, a generally accepted cause of corrosion, were found in all cases except in Group No. 30. To prove that corrosion was a small factor for this group should be possible. For this purpose we note that the cars from which the samples were taken were equipped with a rectifier and a thermostat. These devices account for the finding of only a trace of water and for the very low dilution. These evidences are indicative of warm engines and this, in turn, leads to the expectation of the minimum of corrosion.

EFFECTS OF TEMPERATURES

It will be noted also from Table 8 that the temperatures that prevailed during the period when the 1926 samples served as lubricant are all somewhere near the freezing-point, namely, from 26 to 47 deg. fahr. The corresponding temperatures for the 1925 samples may be seen, either from Fig. 1 or from Table 4, to be fairly represented by an average of about 60 deg. fahr. This difference in temperature is another indication that more corrosion may be expected in the case of the later samples than of those first collected and should help to corroborate further the correctness of the hypothesis relative to the percentage of iron oxide in the ash.

SILICA CONTENT OF THE 1926 SAMPLES INDICATES LITTLE CAUSE FOR WEAR

Arranging the data given in Table 7 according to iron oxide and after compounding similarly as before, we obtain the groups and the weighted average-values given

TABLE 8—DIAGNOSIS OF THE COMPOUNDED 1926 OIL SAMPLES

TABLE 8.—DIAGNOSIS OF ASH CORROSION													
Identification Number of Compounded Samples	Group Designating Make of Car	Number of Samples in Compound	Locality	Ingredients in Terms of Ash, Per Cent			Dilution by Volume, Per Cent	Water by Volume, Per Cent	Temperature Prevailing While Analyzed Samples of Oil Served as Lubricant, Deg. Fahr.	Average Distance for Which Analyzed Samples of Oil Served as Lubricant, Miles	Extra Equipment	Diagnoses	
				Iron Oxide	Silica	Non-Ferrous Metals							
1	2	3	4	5	6	7	8	9	10	11	12		
25	C	4	Dallas	86.8	7.90	3.0	9.0	0.2	49.6	600	Air-Cleaner and Oil Filter	Case 25.—Air-cleaner and oil filter were used making diagnosis uncertain. High percentage of silica indicates that small silica particles pass through both devices.	
26	F	10	Detroit	77.2	11.95	10.0	11.5	8.2	26.7	519		Case 26.—High percentage of iron oxide in ash suggests corrosion. The high percentage of water and the low temperature strengthen the possibility of corrosion.	
27	K	4	Birmingham	92.5	0.00	3.0	12.5	0.4	46.8	484	Oil Filter and Radiator Shutter	Case 27.—Oil filter was used, making diagnosis difficult. Very high percentage of iron oxide strongly suggests corrosion. Fuel usually high in sulphur was used, strengthening the possibility of corrosion.	
28	K	5	Detroit	81.8	0.00	10.0	19.0	6.0	26.7	500		Case 28.—High percentage of iron oxide in ash and zero silica suggests corrosion. High dilution and high percentage of water strengthen the possibility of corrosion.	
29	E	7	Birmingham	70.2	7.20	6.0	16.0	0.6	43.9	496		Case 29.—This is very analogous to Case 22 in Table 4. Fuel usually high in sulphur was used and accounted for high percentage of iron oxide in ash.	
30	H	10	Dallas	57.2	1.40	6.0	8.0	Trace	43.7	587	Thermostat and Rectifier	Case 30.—Unusually low percentage of iron oxide in the ash for this group of samples suggests minimum of corrosion. A rectifier and a thermostat were used, helping to prevent corrosion. Only a trace of water was found and the dilution was extremely low, indicating the efficiency of the rectifier. All these factors favor the minimum of corrosion.	
31	A	3	Atlanta	84.3	1.70	6.0	19.0	2.2	44.9	539	Radiator Shutter	Case 31.—High percentage of iron oxide in the ash suggests corrosion. High dilution and high percentage of water strengthen the possibility of corrosion.	
32	K	7	Atlanta	82.7	0.00	4.0	20.5	5.2	44.9	564		Case 32.—High percentage of iron oxide in the ash suggests corrosion. High dilution and high percentage of water strengthen the possibility of corrosion.	
33	B	10	Birmingham	88.7	2.25	4.2	24.0	3.2	43.9	497		Case 33.—Very high percentage of iron oxide in the ash suggests corrosion. High percentage of dilution and water and the fact that a fuel usually high in sulphur was used considerably strengthen the possibility of corrosion.	

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TABLE 9—1926 OIL SAMPLES GROUPED ACCORDING TO PERCENTAGE OF IRON OXIDE

Groups Based on Iron Oxide Values	Letter Designating Make of Vehicle	Number of Samples in Compound	Locality	Distance Covered by Vehicle While Samples Served as Lubricants, Miles	Total Number of Samples in One Group	Percentage of Ingredients in Compounded Samples Taken from Table 1		Product of Number of Samples Given in Column 3 and Ingredients Given in Column 7	Product of Number of Samples Given in Column 3 and Ingredients Given in Column 8	Ingredients on Basis of 10 Samples	
						Iron Oxide	Silica			Iron Oxide	Silica
1	2	3	4	5	6	7	8	9	10	11	12
<i>k</i>	<i>C</i>	4	Dallas	600	18	0.033	0.004	0.13	0.016	0.0750	0.0097
	<i>F</i>	10	Detroit	519		0.071	0.014	0.71	0.140		
	<i>K</i>	4	Birmingham	484		0.074	0.003	0.44	0.018		
								1.28	0.174		
<i>l</i>	<i>K</i>	5	Detroit	500	22	0.108	0.004	0.54	0.020	0.1380	0.0120
	<i>E</i>	7	Birmingham	496		0.136	0.019	0.95	0.133		
	<i>H</i>	10	Dallas	587		0.164	0.011	1.64	0.110		
								3.03	0.263		
<i>m</i>	<i>A</i>	3	Atlanta	539	20	0.200	0.012	0.60	0.036	0.2415	0.0136
	<i>K</i>	7	Atlanta	564		0.210	0.008	1.47	0.056		
	<i>B</i>	10	Birmingham	497		0.276	0.018	2.76	0.180		
								4.83	0.272		

in Table 9. These correspond as nearly as possible to the values given in Table 5. Sufficient data are available from the 1926 samples for only three groups. If points corresponding to the data given in Columns 11 and 12 are plotted in Fig. 2, Group *k* will be found to come directly in line with Groups *a*, *b*, *c*, and *e* of the former analysis.

However, Groups *l* and *m* are very low in silica for their positions on the iron-oxide scale. This condition, when it occurred together with fair viscosity, was previously taken as suggesting that the iron oxide comes from corrosion. While the viscosities of the 1926 sam-

ples could not be determined, probably they are not so radically different from the 1925 samples that they would necessitate a different method of interpretation of data.

EFFECT OF HIGH PERCENTAGE OF SULPHUR IN FUEL

Finally, the percentages of iron oxide in the ash for the 1926 samples were plotted in Fig. 5 and are represented by points 25 to 29 and by 31. They fall above the graph determined by the points *a*, *b*, *c*, *d*, *e* and *g*. These points were considered as representative of cases in which wear predominated. The 1926 samples, however, come well in line with points *i* and *j* of the 1925

TABLE 10—OIL SAMPLES CLASSIFIED ACCORDING TO PERCENTAGE OF ASH

Percentages of Ash		Number of Samples in Group ⁶ Falling in Range Covered by Subdivision	Proportion of Samples in Group Falling in Range Covered by Subdivision, Per Cent	Number of Samples in Group ⁷ Falling in Range Covered by Subdivision	Proportion of Samples in Group Falling in Range Covered by Subdivision, Per Cent	Number of Samples in Group ⁸ Falling in Range Covered by Subdivision	Proportion of Samples in Group Falling in Range Covered by Subdivision, Per Cent
Range Covered by Subdivisions	Average for the Range						
1	2	3	4	5	6	7	8
0.0000 to 0.0375	0.025	3	6.8	14	3.60	7	3.6
0.0375 to 0.0625	0.050	20	44.5	36	9.30	22	11.2
0.0625 to 0.0875	0.075	5	11.1	38	9.90	9	4.6
0.0875 to 0.1125	0.100	14	31.0	81	21.00	25	12.7
0.1125 to 0.1375	0.125	1	2.2	41	10.60	20	10.1
0.1375 to 0.1625	0.150	....	....	39	10.10	42	21.4
0.1625 to 0.1875	0.175	....	....	30	7.80	17	8.6
0.1875 to 0.2125	0.200	....	....	37	9.60	12	6.1
0.2125 to 0.2375	0.225	....	....	29	7.50	....	....
0.2375 to 0.2625	0.250	....	....	14	3.60	21	10.7
0.2625 to 0.2875	0.275	....	....	12	3.10	7	3.5
0.2875 to 0.3125	0.300	1	2.2	....	....	5	2.5
0.3125 to 0.3375	0.325	....	....	....	....	....	....
0.3375 to 0.3625	0.350	....	....	10	2.60	....	....
0.3625 to 0.3875	0.375	....	....	4	1.04	....	....
0.3875 to 0.4125	0.400	1	2.2	....	....	....	....
0.4125 to 0.4375	0.425	....	....	....	....	....	....
0.4375 to 0.4625	0.450	....	....	....	....	10	5.0
0.4625 to 0.4875	0.475	....	....	1	0.26	....	....

⁶ This group consisted of 41 vehicles of the 1926 survey which were equipped with air-cleaners or oil filters or both.

⁷ This group consisted of 386 vehicles of the 1926 survey which were not equipped with air-cleaners and oil filters; cars for which the equipment is unknown are included in this group.

⁸ This group consisted of 197 vehicles of the 1925 survey which were not equipped with air-cleaners and oil filters; cars for which the equipment is unknown are included in this group.

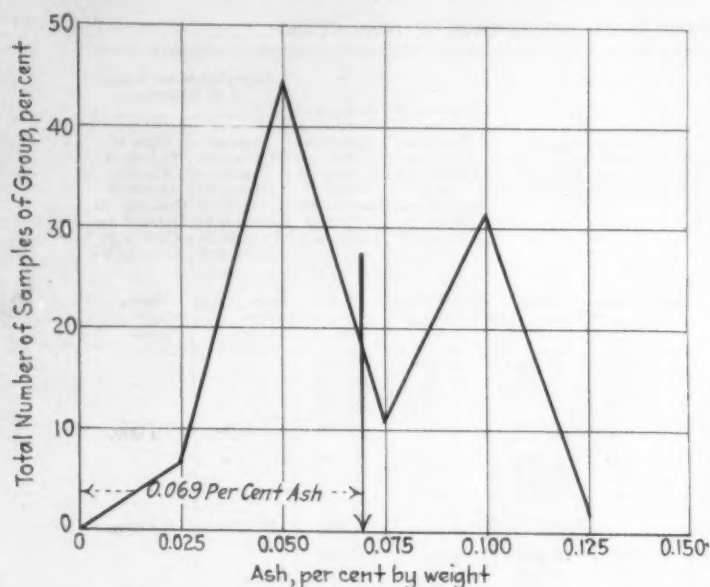


FIG. 6—COLUMNS 2 AND 4 OF TABLE 10 COMPARED
The Percentages in Column 4 Are Plotted against the Average Percentages of Ash in Column 2. For the Group Considered Here, the Average Ash Fairly Representing All Samples Is About 0.069 Per Cent

analysis. For the latter points, it was rather definitely established that they represent conditions in which corrosion predominated. They were made up from samples taken from cars that used fuel which usually is high in sulphur. Points 25 to 29 and 31 represent compounded samples instead of groups of compounded samples. The reason for this slight departure is that when grouping together 25 samples only three points would have been obtained and two of these fell beyond the limits of the chart.

These remarks, together with the individual diagnosis given in Table 8, will help to complete and to corroborate the work described earlier in the paper.

SIGNIFICANCE OF ASH

That in the 1926 samples the ash, the dilution and the water should be studied, rather than the ingredients in the ash, was stated previously. Moreover, the request was made that in the collection of the 1926 samples an indication should be given on the record sheets if the cars from which the oil was taken were equipped with an air-cleaner, an oil-filter, a rectifier, a hood cover, a manifold heater, a radiator shutter, or a thermostat. The records given with regard to this equipment, al-

though perhaps not complete, are useful for separating the data given in Table 6 into groups representing cars according to their equipment. The effect that this equipment has on contamination can be studied by comparison. The study consists mainly of graphical representations. In these, the percentages of the contaminating substance have been chosen as abscissas. The percentages of that number of vehicles constituting whatever particular group may be under consideration are plotted as ordinates.

EFFECT OF AIR-CLEANERS AND OIL-FILTERS

In connection with the ash, samples obtained from cars equipped with air-cleaners and oil-filters obviously should be studied together in one group. From Table 6 it will be noted that 45 cars were so equipped in the 1926 survey. These 45 cars are classified according to the percentage of ash that was found in the oil sample. The details of the procedure that was followed are self-evident from Table 10. In Column 1 of Table 10 are given the limits of the 20 ranges into which the maximum ash-content found in the group has been subdivided. Column 2 gives the mean values corresponding to the minimum and the maximum values given in Column 1. In Column 3, the number of samples that had an ash content equal to or smaller than the maximum but larger than the minimum indicated in Column 1 is given. Column 4 represents the percentage that the figures given in Column 3 constitute of the total number of samples or cars in the group under consideration.

The percentages given in Column 4 of Table 10 are plotted in Fig. 6 against the average percentages of ash given in Column 2 of Table 10. The graphical representation is not carried beyond 0.125 per cent ash, inasmuch as the two isolated cases that follow very likely represent either very extraordinary conditions or defective equipment. That for the group here considered the average ash fairly representing all samples is about 0.069 per cent will be noted from Fig. 6.

Columns 5 and 6 of Table 10 have been prepared in an entirely similar manner to that used for Columns 3 and 4. The difference is that the samples represented in Columns 5 and 6 were taken from cars without air-cleaners and oil-filters. Included in this group are also those samples that were received without records as to the equipment used on the cars. The data from Column 6 were used to plot Fig. 7, the procedure being analogous to that followed in plotting Fig. 6. The average ash representing all samples in this group is 0.134 per cent. Similarly to the previous procedure, a few extreme cases

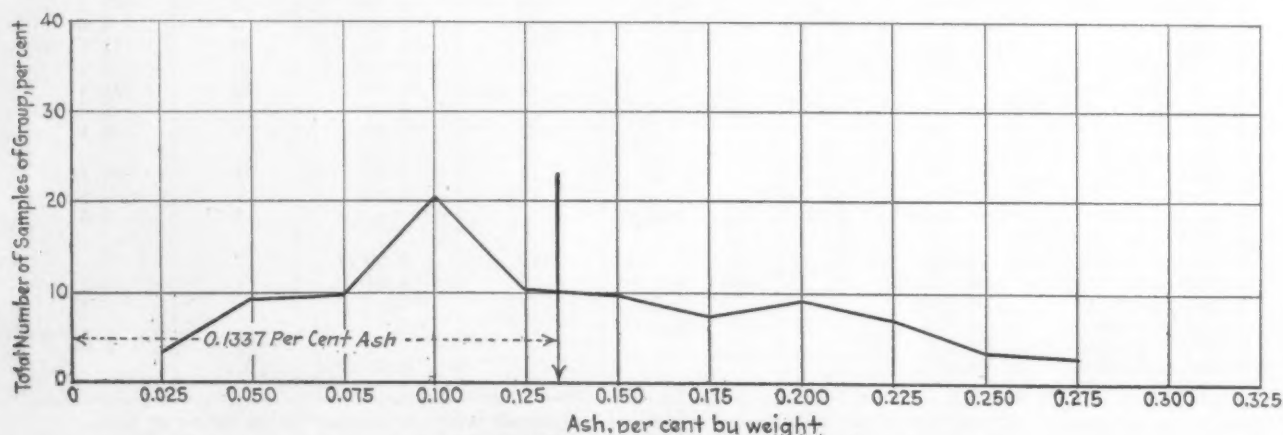


FIG. 7—DATA FROM COLUMN 6 OF TABLE 10 SHOWN GRAPHICALLY
The Procedure Was Analogous to That Followed in Plotting Fig. 6. The Samples Were Taken from Cars Not Equipped with Air-Cleaners and Oil-Filters. The Average Ash Representing All Samples in This Group Is 0.134 Per Cent

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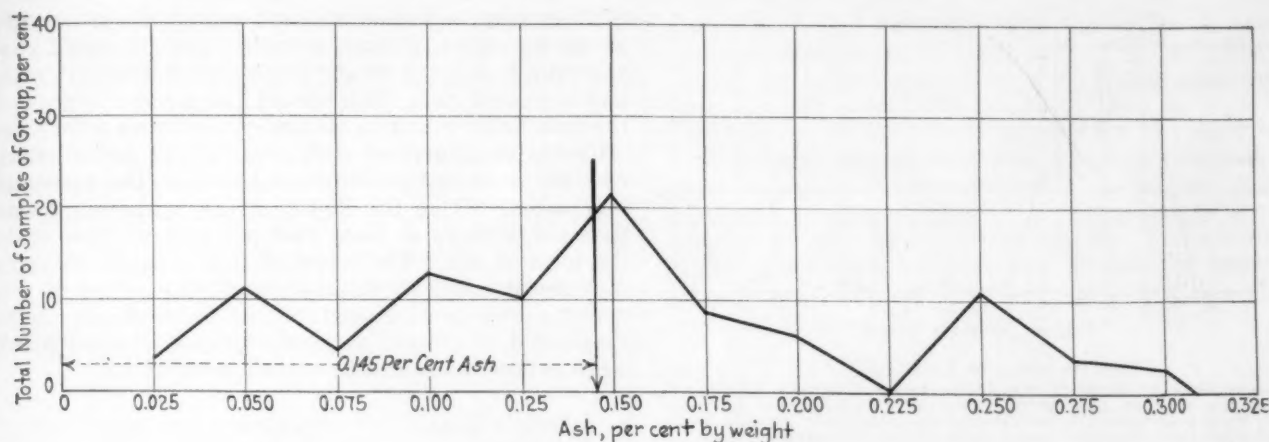


FIG. 8—COMPARISON OF RESULTS

This is a Graphical Representation of Results That are Fairly Comparable with Those Shown in Fig. 7. The Average Ash Representing All Samples of This Group is 0.145 Per Cent, or about 8.000 Per Cent More Than in the Case of the 1926 Samples

have been omitted. From a comparison of Figs. 6 and 7 the oil-filter and the air-cleaner appear to reduce the ash or, more particularly, the contaminating ingredients of the lubricating-oil that are found in the ash, to about one-half the proportion that is usually found if this equipment is not used.

COMPARISON OF RESULTS FROM BOTH SURVEYS

Columns 7 and 8 were added to Table 10 to afford a comparison of the results obtained from the 1926 samples with those obtained from the 1925 samples. The necessary data were taken from Table 1. In the 1925 survey, very few cars were known to be equipped with air-cleaners and oil-filters. Therefore, a special investigation to give results for the 1925 samples that would be directly comparable to those given in Fig. 6 had to be omitted. The

TABLE 11—PERCENTAGES OF IRON OXIDE IN ASH FROM 1925 SURVEY SAMPLES

Identification Number of Compounded Samples	Group Designating Make of Car	Number of Samples in Compound	Locality	Iron Oxide in Ash, Per Cent	Product of Number of Samples Given in Column 3 and Percentage Given in Column 5
1	2	3	4	5	6
<i>Samples Representative of Wear</i>					
1	F	12	Detroit	74.4	893
1a	C	7	Oklahoma City	59.4	415
3	F	10	City of Washington	72.7	727
4	B	4	Detroit	53.4	214
5	B	9	Minneapolis	66.7	600
6	E	3	Birmingham	57.4	172
7	C	10	New Orleans	72.0	720
9	B	7	Detroit	65.6	459
10	E	10	Tulsa	60.0	600
11	D	4	Oklahoma City	66.7	267
12	E	10	Detroit	57.0	570
13	E	10	San Francisco	58.6	586
14	I	11	Detroit	65.0	715
14a	G	9	New Orleans	62.2	560
16	H	6	Detroit	84.1	504
19	A	11	Detroit	68.1	750
24	B	10	Oklahoma City	65.7	657

Grand Average Percentage of Iron Oxide in Ash: 65.7 Per Cent.

Samples Representative of Corrosion

Identification Number of Compounded Samples	Group Designating Make of Car	Number of Samples in Compound	Locality	Iron Oxide in Ash, Per Cent	Product of Number of Samples Given in Column 3 and Percentage Given in Column 5
1	2	3	4	5	6
8	C	8	Birmingham	74.4	595
15	A	11	San Francisco	78.2	860
17	A	6	Atlanta	84.5	507
18	K	5	Birmingham	94.3	471
18a	H	11	Birmingham	87.6	965
20	B	12	Birmingham	77.5	930
21	F	10	San Francisco	71.5	715
22	E	7	Birmingham	69.5	486
23	K	5	Birmingham	80.4	402

Grand Average Percentage of Iron Oxide in Ash: 79.1 Per Cent.

TABLE 12—PERCENTAGE OF IRON OXIDE IN ASH FROM 1926 SURVEY SAMPLES

Identification Number of Compounded Samples	Group Designating Make of Car	Number of Samples in Compound	Locality	Iron Oxide in Ash, Per Cent	Product of Number of Samples Given in Column 3 and Percentage Given in Column 5
1	2	3	4	5	6
25	C	4	Dallas	86.8	348
26	F	10	Detroit	77.2	772
27	K	4	Birmingham	92.5	370
28	K	5	Detroit	81.8	409
29	E	7	Birmingham	70.2	491
31	A	3	Atlanta	84.3	253
32	K	7	Atlanta	82.7	580
33	B	10	Birmingham	88.7	887
		50			4,110

Grand average percentage of iron oxide in ash: 82.2.

data in Columns 7 and 8 of Table 10 represent cars that were known to have no air-cleaner or oil-filter and also those for which records about the equipment were not received. Fig. 8 represents graphically results that are fairly comparable with those given in Fig. 7. The average ash representing all samples of this group is 0.145 per cent, or about 8.000 per cent more than in the case of the 1926 samples. Since the latter samples were more representative of winter conditions than the 1925 samples, the ash in the oil appears to be slightly less in winter than in summer; however, we must bear in mind that the number of samples obtained in the 1925 survey is only about half as large as the number in the 1926 survey. Consequently, the two should be compared with each other with that qualification in mind. Because the difference is very small, the state of affairs with regard to the percentages of ash found might very likely be reversed if the number of samples constituting the 1925 survey had been twice as large. In spite of the qualification, the results are rather contrary to expectations.

The condition is entirely different with regard to the percentage of iron oxide found in the ash. From Table 1 the grand average-percentage of iron oxide in the ash for the 1925 samples is seen to be 71 per cent. If we

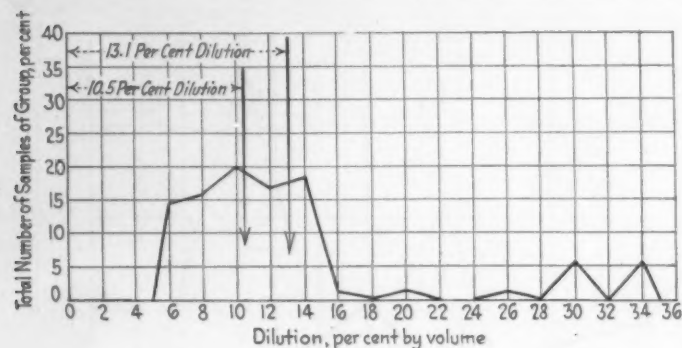


FIG. 9—DATA ON DILUTION

The Percentages of Cars of the First Group Given in Line 4 of Table 13 Are Plotted Against the Average Percentage of Dilution Given in Line 2 of Table 13. Of the 71 Samples, Only 10 Had More Than 16-Per Cent Dilution. Assuming These 10 Unusual Cases To Be Representative of Extreme Conditions, the Average Dilution for the 61 Is 10.5 Per Cent; and for the 71 Samples It Is 13.1 Per Cent

separate these samples into two groups, one containing only those samples that, according to the diagnoses given in Table 4, were representative of conditions under which corrosion very likely took place, and the other containing only those samples that were representative of conditions under which wear predominated, we obtain according to Table 11 a percentage of iron oxide in the ash for the first group of 79.1 per cent.

In studying the grand average of iron oxide in the ash for the 1926 samples from the data given in Table 8, we take all samples except No. 30. From these eight cases we obtain, according to the familiar compilation given in Table 12, the grand average of iron oxide in the ash of 82.2 per cent. The margin of difference between the figure representing wear, 65.7 per cent, and corrosion,

82.2 per cent, is substantial and can hardly be considered as accidental or of such a nature that it would change radically if a much larger or smaller number of samples had been analyzed. This should again serve to prove that the iron oxide found in the ash can serve as a very useful criterion to determine within certain limits of accuracy whether corrosion or abrasion has been the predominating factor. From the figures given, corrosion seems to have contributed at least 16.5 per cent of iron oxide to the total of ash. The collection and analysis of samples representing strictly summer conditions should of course reveal a still greater contrast, as no doubt the samples considered at present as representative of wear are to a large extent influenced by some corrosion.

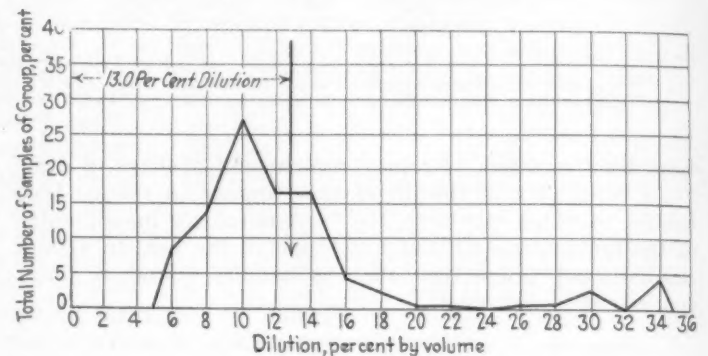


FIG. 10—DILUTION DATA FROM CARS HAVING AUXILIARY EQUIPMENT The Chart Is Analogous to Fig. 9 Except That It Represents Samples from Cars That Were Equipped with a Rectifier or a Thermostat or a Radiator Shutter, or with Two of These Devices. The Average Dilution, Considering 132 Samples, Was 13 Per Cent. When Comparing Fig 9 and 10, the Fact That One Group Consists of 71 and the Other Group of 132 Samples Must Be Borne in Mind

TABLE 13—OIL SAMPLES CLASSIFIED ACCORDING TO PERCENTAGE OF DILUTION

Range covered by subdivision, per cent.....	1	5 to 7	7 to 9	9 to 11	11 to 13	13 to 15	15 to 17	17 to 19	19 to 21	21 to 23	23 to 25	25 to 27	27 to 29	29 to 31	31 to 33	33 to 35	35 to 37	37 to 39	39 to 41	41 to 43	43 to 45
Average for the range given.....	2	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44
Number of samples in group ⁹ falling within range covered by subdivision.....	3	10	11	14	12	13	1	.....	1	.....	.....	1	.....	4	.....	4	.....	.....	.....	.....	.....
Proportion of samples in group falling within range covered by subdivision, per cent.....	4	14.10	15.5 ¹⁰	19.70	16.90	18.30	1.40	.....	1.40	.....	.....	1.40	.....	5.65	.....	5.65	.....	.....	.....	.....	.....
Number of samples in group ¹⁰ falling within range covered by subdivision.....	5	11	18	36	22	22	6	3	1	1	.....	1	1	4	.....	6	.....	.....	.....	.....	.....
Proportion of samples in group falling within range covered by subdivision, per cent.....	6	8.34	13.60	27.30	16.70	16.70	4.51	2.30	0.76	0.76	.....	0.76	0.76	3.00	.....	4.51	.....	.....	.....	.....	.....
Number of samples in group ¹¹ falling within range covered by subdivision.....	7	7	21	37	34	45	25	71	17	11	11	2	9	.....	1	7	.....	.....	.....	.....	1
Proportion of samples in group falling within range covered by subdivision, per cent.....	8	2.30	7.00	12.40	11.40	15.10	8.40	23.70	5.70	3.70	3.70	0.70	3.00	.....	0.30	2.30	.....	.....	.....	.....	0.30
Number of samples in group ¹² falling within range covered by subdivision.....	9	7	27	57	44	54	30	71	16	12	11	10	10	.....	1	9	.....	.....	.....	.....	1
Proportion of samples in group falling within range covered by subdivision, per cent.....	10	2.00	7.50	15.80	12.20	15.00	8.30	19.70	4.40	3.30	3.10	2.80	2.80	.....	0.30	2.50	.....	.....	.....	.....	0.30
Number of samples in group ¹³ falling within range covered by subdivision.....	11	10	38	14	25	34	28	28	37	9	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Proportion of samples in group falling within range covered by subdivision, per cent.....	12	4.50	17.40	6.20	11.10	15.60	12.40	12.40	16.40	4.00	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

⁹ This group consisted of 71 vehicles of the 1926 survey which were equipped with oil rectifiers.

¹⁰ This group consisted of 132 vehicles of the 1926 survey which were equipped with an oil rectifier, a thermostat, a radiator shutter, or some two of these devices.

¹¹ This group consisted of 299 vehicles of the 1926 survey which were not equipped with oil rectifiers, thermostats or radiator shutters. Vehicles for which no record of their equipment was furnished are included in this group.

¹² This group consisted of 360 vehicles of the 1926 survey or all except those which were equipped with an oil rectifier.

¹³ This group consisted of 223 vehicles of the 1925 survey or all except 2 that were equipped with oil rectifiers.

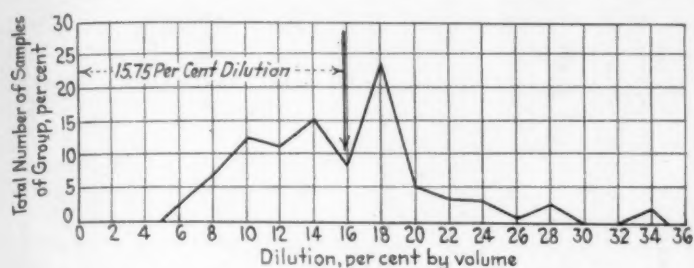


FIG. 11—DILUTION DATA FROM CARS WITHOUT AUXILIARY EQUIPMENT No Device for Preventing Dilution Was Used on the Cars. Samples for Which No Record Relative to Special Equipment Was Furnished Are Also Included in This Group. The Average Dilution for the 299 Samples Represented Is 15.75 Per Cent

DIFFERENCES OF DILUTION FOR VARIOUS GROUPS

The subject of oil dilution has been studied by many and has been presented by many authors. The following comments on dilution are therefore not expected to reveal anything particularly new; however, the material from which these comments are derived is far more voluminous than that at the disposal of other investigators. This was considered a good reason for repeating here an analysis that in some respects has been recorded previously. The main object of this investigation is to furnish a basis for determining the effectiveness of devices such as rectifiers, thermostats and radiator shutters in preventing dilution. We shall again divide the data obtained from the 1926 survey as given in Table 6 into several groups, one representing samples obtained from cars that were equipped with rectifiers, another representing those obtained from cars that were equipped with either a rectifier or a thermostat or a radiator shutter or with two of these devices and a third

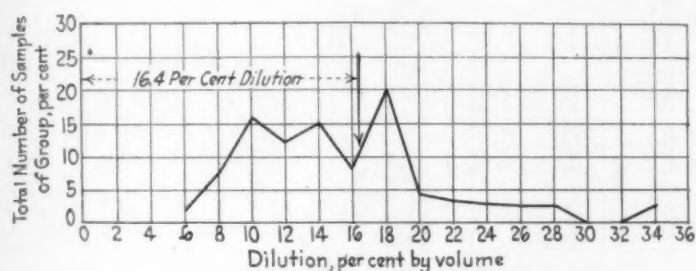


FIG. 12—COMPARISON OF 1925 WITH 1926 SAMPLES The Chart Was Prepared To Make the Results from the 1926 Samples Comparable with Those from the 1925 Samples. The Average Dilution Is 16.4 Per Cent

for cars that had neither of these devices. In the last-named group are included also those cars for which no record of the equipment was furnished. In Group 4 are given all the cars of the 1926 survey except those that were equipped with a rectifier. In Group 5, all cars of the 1925 survey are given except two that were equipped with rectifiers. The latter two groups represent equal conditions except for the difference in season or, rather, in atmospheric temperatures that prevailed while the samples under consideration served as a lubricant.

Table 13 has been compiled from data on dilution in an entirely similar manner as that in which Table 10 was prepared for data on ash. The percentages of cars of the first group given in Line 4 of Table 13 are plotted in Fig. 9 against the average percentage of dilution given in Line 2 of Table 13. Of the 71 samples only 10 had more than 16-per cent dilution. If we assume that these 10 unusual cases are representative of extreme conditions, we obtain an average dilution for the 61

samples of 10.5 per cent. For the entire 71 cases, the average dilution is 13.1 per cent. By "extreme conditions" we understand cases in which the cars were not operated for a sufficient length of time to warm up the rectifier or the device was inoperative for other reasons.

Fig. 10 is analogous to Fig. 9 in every respect except that it represents samples taken from cars that were equipped with a rectifier or a thermostat or a radiator shutter or with two of these devices. The average dilution, taking into consideration all the 132 samples, although some are obviously extremes, is 13 per cent. In comparing these two groups we must bear in mind that

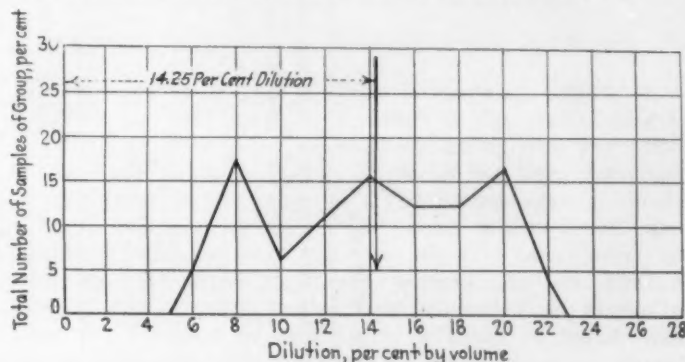


FIG. 13—DATA FROM SAMPLES COLLECTED IN 1925 This Chart Is Analogous to Fig. 12. The Difference in the Average Dilution for the Two Surveys Is Slightly More Than 2 Per Cent

one group consists of 71 samples and the other of 132. The results, however, as given by the averages for the groups, should prove of interest.

Fig. 11 is analogous to both Fig. 9 and 10 in every respect except that it represents samples taken from cars that were equipped with no device that effectively prevents dilution. Included in this group are also those samples for which no record was furnished relative to

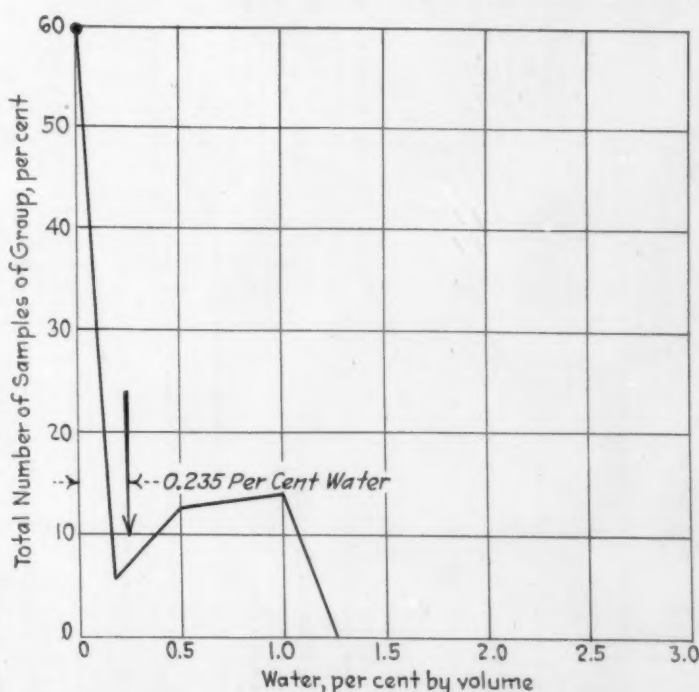


FIG. 14—FACTORS INFLUENCING THE ACCUMULATION OF WATER The Percentages Given in Line 4 of Table 14 Refer to Samples That Were Taken from Cars Equipped with a Rectifier and These Are Plotted Against the Average Percentages of Water as Given in Line 2 of Table 14. The Arrow Indicates That the Average Percentage of Water for the 71 Samples Under Consideration Is 0.235

TABLE 14—OIL SAMPLES GROUPED ACCORDING TO PERCENTAGE OF WATER

	1	Trace	0.100 to 0.250	0.250 to 0.500	0.500 to 1.000	1.000 to 1.500	1.500 to 2.000	2.000 to 2.500	2.500 to 3.000	3.000 to 3.500	3.500 to 4.000	4.000 to 4.500	4.500 to 5.000	5.000 to 5.500	5.500 to 6.000	6.000 to 6.500	6.500 to 7.000	7.000 to 7.500	7.500 to 8.000	8.000 to 8.500	8.500 to 9.000	9.000 to 9.500	Over 9.500
Range covered by subdivision, per cent	1	Trace	0.100 to 0.250	0.250 to 0.500	0.500 to 1.000	1.000 to 1.500	1.500 to 2.000	2.000 to 2.500	2.500 to 3.000	3.000 to 3.500	3.500 to 4.000	4.000 to 4.500	4.500 to 5.000	5.000 to 5.500	5.500 to 6.000	6.000 to 6.500	6.500 to 7.000	7.000 to 7.500	7.500 to 8.000	8.000 to 8.500	8.500 to 9.000	9.000 to 9.500	Over 9.500
Average for the range given	2	.....	0.125	0.375	0.750	1.250	1.750	2.250	2.750	3.250	3.750	4.250	4.750	5.250	5.750	6.250	6.750	7.250	7.750	8.250	8.750	9.250	.....
Number of samples in group ¹⁴ falling within range covered by sub-division	3	43	4	9	10	.....	.....	.....	.....	4	.....	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Proportion of samples in group falling within range covered by sub-division, per cent	4	60.700	5.600	12.700	14.000	.....	.....	.....	.....	5.600	.....	1.400	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Number of samples in group ¹⁵ falling within range covered by sub-division	5	55	12	27	10	8	.....	3	1	11	.....	1	.....	.....	.....	.....	3	.....	.....	1	.....	.....	.....
Proportion of samples in group falling within range covered by sub-division, per cent	6	41.800	9.100	20.400	7.600	6.080	.....	2.300	0.760	8.360	.....	0.760	.....	.....	.....	.....	2.300	.....	.....	0.760	.....	.....	.....
Number of samples in group ¹⁶ falling within range covered by sub-division	7	43	23	85	50	14	15	24	10	1	.....	.....	8	.....	.....	5	7	1	.....	10	.....	.....	3
Proportion of samples in group falling within range covered by sub-division, per cent	8	14.400	7.700	28.500	16.700	4.700	5.000	8.000	3.340	0.334	.....	.....	2.670	.....	.....	1.670	2.340	0.334	.....	3.340	.....	.....	1.000
Number of samples in group ¹⁷ falling within range covered by sub-division	9	57	37	81	64	23	12	18	11	8	.....	28	.....	.....	.....	6	7	4	.....	1	.....	.....	3
Proportion of samples in group falling within range covered by sub-division, per cent	10	15.800	10.300	22.500	17.800	6.400	3.300	5.000	3.060	2.200	.....	7.800	.....	.....	.....	1.670	1.950	1.110	.....	0.280	.....	.....	0.830
Number of samples in group ¹⁸ falling within range covered by sub-division	11	92	48	20	6	.....	57	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Proportion of samples in group falling within range covered by sub-division, per cent	12	41.300	21.300	8.900	2.700	.....	25.800	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

¹⁴ This group consisted of 71 vehicles of the 1926 survey which were equipped with oil rectifiers.

¹⁵ This group consisted of 132 vehicles of the 1926 survey which were equipped with an oil rectifier, a thermostat, a radiator shutter, or some two of these devices.

¹⁶ This group consisted of 299 vehicles of the 1926 survey which were not equipped with oil rectifiers, thermostats or radiator shutters. Vehicles for which no record of their equipment was furnished are included in this group.

¹⁷ This group consisted of 360 vehicles of the 1926 survey or all except those which were equipped with an oil rectifier.

¹⁸ This group consisted of 223 vehicles of the 1925 survey or all except 2 that were equipped with oil rectifiers.

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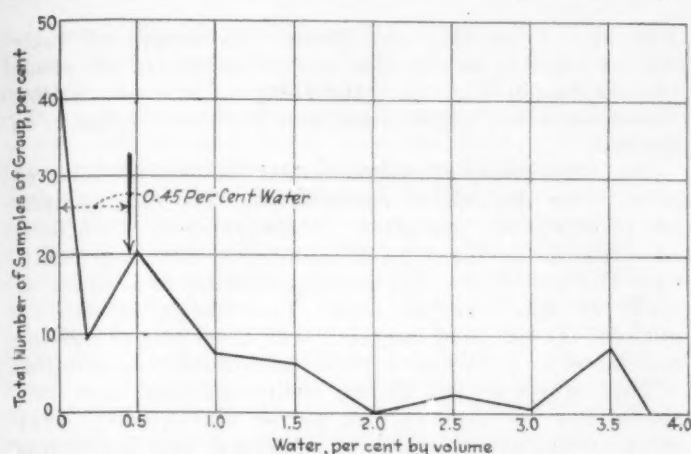


FIG. 15—DATA ON THE ACCUMULATION OF WATER OBTAINED FROM CARS HAVING AUXILIARY EQUIPMENT

The Samples Were from Cars That Were Equipped with a Rectifier, a Thermostat, a Radiator Shutter, or with Two of These Devices, the Corresponding Data from the 132 Cars Being Compiled in Lines 5 and 6 of Table 14. The Arrow Indicates That the Accumulation of Water for the Group Is 0.45 Per Cent, or Very Nearly Twice as Much as for the Group of Cars Equipped with Rectifiers

special equipment. The numerical values used for the plotting of this figure are given in Lines 7 and 8 of Table 13. That the average dilution for the 299 samples represented is 15.75 per cent should be noted. Fig. 11, when compared with Fig. 9 and 10, clearly indicates that the dilution-preventing devices are rendering useful service.

Fig. 12 was prepared to make the results obtainable from the 1926 samples as nearly as possible comparable with those of the 1925 samples. The data for the plotting of Fig. 12 are given in Lines 9 and 10 of Table 13. Represented in this group are samples from all cars not

equipped with rectifiers. The average dilution is 16.4 per cent. When comparing Fig. 12 with Fig. 9, we obtain approximately the effect that a rectifier has on dilution. It is, however, again necessary to compensate for numbers of representation.

Fig. 13 is analogous in every respect to Fig. 12 except that it represents samples collected in 1925. It will be noted that the difference in the average dilution for the two surveys is slightly over 2 per cent. The difference in the atmospheric temperatures that was previously pointed out as distinguishing the 1925 from the 1926 samples is noticeable in the average dilution, although not nearly to the extent that might be expected.

FACTORS INFLUENCING ACCUMULATION OF WATER

In the following text a study is made of factors that influence the accumulation of water in the crankcase oil. We shall again divide the data obtained from the 1926 survey into several groups. Table 14 has been compiled to correspond with Table 13. The percentages given in Line 4 refer to samples that were taken from cars equipped with a rectifier. In all, 71 cars were so equipped. In Fig. 14, these percentages are plotted against the average percentages of water as given in Line 2. Samples in which only a trace of water was found were taken together with those having no water. The difference between no water and a trace of water is perhaps in actual figures about 0.01 per cent, and this is too small a difference to become apparent in graphical representation of a scale that had to be chosen in this paper. The arrow shown in Fig. 14 indicates that the average percentage of water for the 71 samples under consideration is 0.235.

The second group to be considered comprises samples

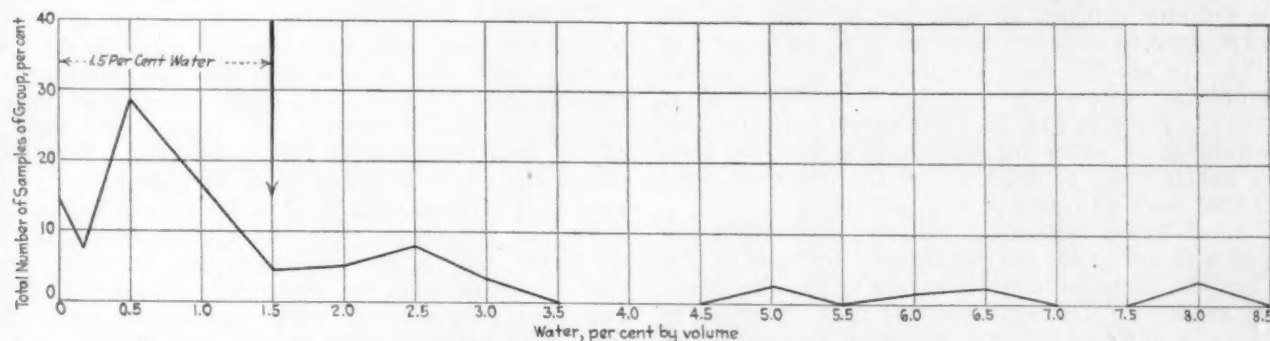


FIG. 16—DATA FROM CARS NOT EQUIPPED WITH ANY DEVICES

The Corresponding Data Are Given in Lines 7 and 8 of Table 14. The Arrow Indicates That the Average of the Water Accumulation for the Group Is 1.5 Per Cent

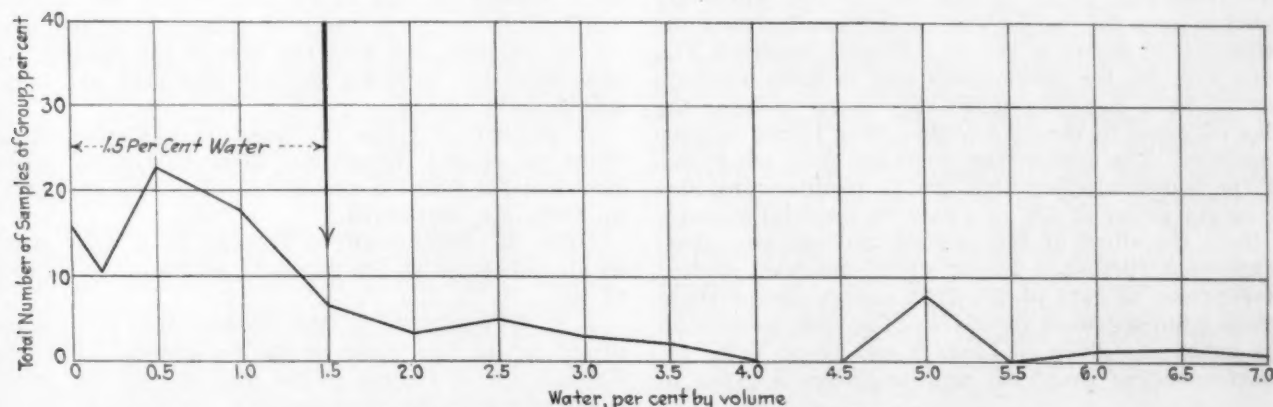


FIG. 17—FURTHER DATA ON CARS OF THE 1926 SURVEY

All Cars of the 1926 Survey Except Those Equipped with Rectifiers Are Included and the Data Pertaining to This Group Are Given in Lines 9 and 10 of Table 14. The Average Percentage of Water Is the Same as for the Cars of the Group Represented in Fig. 16

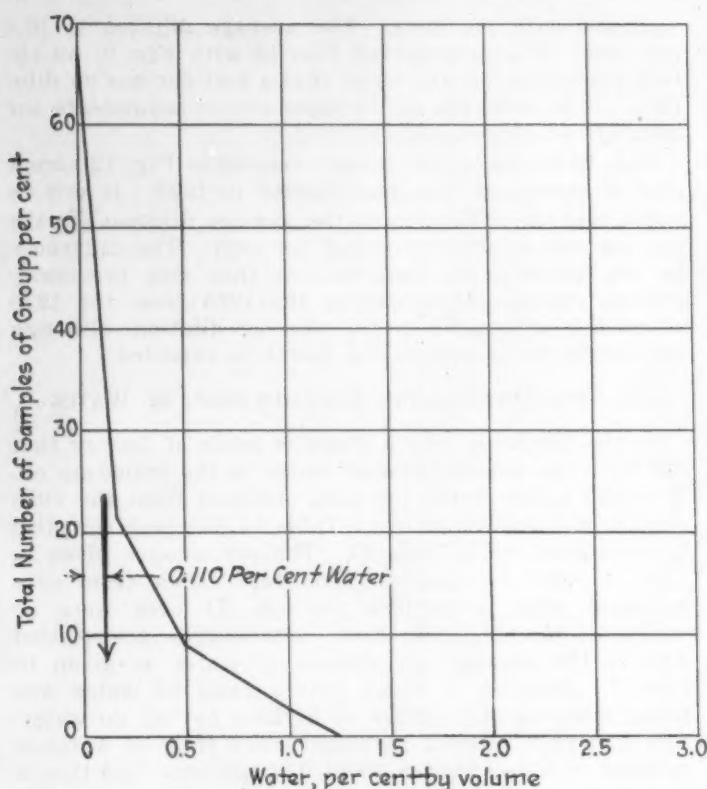


FIG. 18—DATA FOR ALL CARS OF THE 1925 SURVEY EXCEPT TWO EQUIPPED WITH RECTIFIERS

Lines 11 and 12 of Table 14 Present the Data for This Group. The Arrow Indicates an Average of Water Accumulation of Only 0.11 Per Cent. This Is Comparable with 1.5 Per Cent for the 1926 Samples

from cars that were equipped with a rectifier, a thermostat, a radiator shutter, or with two of these devices. The corresponding data are compiled in Lines 5 and 6 of Table 14. In all, 132 cars are included in this group. The graphical representation of the data pertaining to this group is given in Fig. 15. The arrow indicates that the percentage of water for the group is 0.45 per cent, or very nearly twice as much as for the previous group of cars that were all equipped with rectifiers.

The third group comprises all cars that were not equipped with any of the devices stated. Included in this group are also those for which a record of the equipment was not available. The corresponding data are given in Lines 7 and 8 of Table 14. The graphical representation is given in Fig. 16. The arrow indicates that the average of the water for the group is 1.5 per cent. It is evident from Fig. 14 to 16 that the devices which are intended to keep the engine warm prevent effectively the accumulation of water in the oil. When comparing Fig. 15 with Fig. 16, the thermostats and radiator shutters appear to have helped considerably more to keep the average of water in the oil low than they helped to keep dilution low. The comparison, however, does not reveal fairly the beneficial effect that the 71 rectifiers included in the second group of 132 cars have on the total average.

To trace the effect of thermostats and radiator shutters somewhat further, a fourth group has been studied that comprises all cars of the 1926 survey except those that were equipped with rectifiers. The data pertaining to this group are given in Lines 9 and 10 of Table 14. The corresponding graphical representation is given in

Fig. 17. From this the average percentage of water will be found to be the same as for the cars of the group represented in Fig. 16. According to this comparison, thermostats and radiator shutters still leave much to be desired.

The fifth group comprises all cars of the 1925 survey except two that had rectifiers fitted. The data pertaining to this group are given in Lines 11 and 12 of Table 14. Fig. 18 is the corresponding graphical representation of these data. The arrow indicates an average of water of only 0.11 per cent. This compares with 1.5 per cent for the 1926 samples. The difference is striking and far more pronounced than the difference in dilution.

The interpretation of the entire material here presented has not been carried as far as I hoped. Many other combinations could be arranged and interesting results obtained. However, the information here given on this extensive survey and shown in Fig. 1, 2, 6, and 7, can be taken by any interested person and elaborated or at least the interpretation can be carried further. This is particularly recommended to some of our universities.

The entire project was made possible only through the cooperation of about 100 different organizations and individuals. The names of all these participants would make a very lengthy list for the average reader to study. Moreover, in a large project of this kind overlooking someone who has done as much for the project as others that are mentioned is very easy. Thanks are given herewith collectively to all who helped in any form to make this work possible. I hope that the results given will in part compensate for the trouble incurred by the participants.

THE DISCUSSION

CHAIRMAN H. C. MOUGEY¹⁸:—A number of different automobile companies have tried to cover in their work a very small part of this field that Mr. Burkhardt has covered, but the companies experienced great difficulty in securing the information even from a very small part of the field representing their own cars. This survey covers the entire field and gives an opportunity to compare what is happening in all of the cars in the industry.

Several years ago, when we first started this work, we found that a general impression prevailed among men connected with the automobile industry that their own cars were perfect, while competitors' cars admittedly were having a little trouble with dilution and corrosion. The data that Mr. Burkhardt has submitted show that all automobiles are troubled with these things to a greater or less extent and enable the automobile builders to compare their own cars with the average of the industry and with the best in the industry to see just what the different devices that they are adopting are actually doing.

A number of times the question has come up as to when we should change oil; after how many miles, or how bad the dilution should be. Can you say anything on that, Mr. Burkhardt?

OTTO M. BURKHARDT:—Mileage is a hazy measure as an indication of the necessity or the need for change of oil.

J. F. WINCHESTER¹⁹:—Mr. Burkhardt is to be congratulated on the fine paper he has presented. In the paper I find a direct answer to the majority of the questions that the committee investigating the subject desired to have answered. I notice that no further samples have been collected or the work carried along. No specific solution seems to be given or recommendations made

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¹⁹ M.S.A.E.—Supervisor of motor equipment, Standard Oil Co. of New Jersey, Baltimore.

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for curing the ills that brought on the study. It should be the work of the Society to continue this work and carry it along until something definite is suggested.

My thought along that line can be expressed in these words. Mr. Burkhardt has used the work of the medical profession as an analogy in connection with the analyzing of oil. The medical profession would certainly not take a sample of blood without knowing the condition of the patient. They would base their final conclusions upon the condition of the patient as well as on the sample of blood. That is the line of thought that I have. In this particular paper, or the work that has been done to date, no measurements at all have been taken on the engines that the samples of oil have been drawn from. To me this seems to be a mistake. That a certain material is found in the oil does not mean necessarily that the wear in one engine is in the same proportion as it is in another or that the engine did not function properly. That, in a certain degree, depends upon the location of the pump, the filtering system and the general design of the engine. Therefore, I think that if we are to get direct benefits from this work, or work that is done in the future, we should proceed on different lines than in the past.

In this paper considerable stress is laid upon the economical use of oil. Personally, I think that oil in general operation represents practically 2 per cent of the total operating cost of a complete motor-vehicle of any type; I feel that 2 per cent is the maximum figure. Labor and finished metal cost much more, and I am certain that we are not wasting oil, as we save on those items which are also incidentals as compared to lost vehicle-service under some conditions.

The public, in changing the oil at certain set mile-ages, say 500 or 700 miles, is protecting itself against undue wear until the time comes when we can have more conclusive evidence than we have at present that oil does not break-down or that the material being circulated through the oil does not do material damage to the vehicle itself. I think that changing oil every 500 or 700 miles is a form of insurance until such time as it shall be indicated definitely that filtering devices of one kind or another will prolong the life of the oil.

The Research Department can hardly say that the majority of the men in the country are wrong when it has not proved conclusively that the research itself is conclusive.

In connection with that, I might say that while these samples have been taken throughout the entire Country, with the large number of motor-vehicles that are built with different types of engine head today, we should be able to go outside of the line of manufacture and the service stations and get large fleet operators, who would be perfectly willing to cooperate with the Society, to take measurements periodically on their vehicles and report them to the Society. In the long run, a research like that would be of considerably more value than the one we have conducted. It would coordinate the various factors involved.

W. R. STRICKLAND²¹:—I am rather surprised at the last speaker's remarks, as I thought the matter presented by Mr. Burkhardt and the way it was presented were very convincing. I think that most of the automobile companies in the Country have started with the condition of the patient; the first symptoms have been the condition of the patient. The patient showed differences of wear and corrosion. Blood analyses were made

and the condition of the patient studied from that standpoint. To be sure, the Society has not presented the latter side of the question, but the manufacturers have considerable information along that line.

The company I am connected with had, I might say, considerable trouble in certain localities. The matter has been studied for probably 3 years. The question of dilution, water content, ash, and similar matters was studied carefully as well as the conditions under which they appeared, and the conditions under which the oil and fuel were used in the different communities. The conclusions we have reached have been borne out by this study presented here today.

I think by far the greatest damage to the patient which would show up in warm parts, all cast iron and steel parts in the engine, came directly from the water content that came with dilution. The study proved that the temperature of the engine, the method under which it was operated producing the mean temperature of the engine, and the chemical content of the fuel combined produced corrosion which gave us most of our trouble. The spots are very definite. They were shown on the charts, and we who have studied the subject know just where they were and the cause.

We have introduced a system. We used thermostats which help keep the temperature up; we used shutters to help keep the temperature up; and we now have a ventilating system on a crankcase to take out the moisture. At the same time that we take out the moisture, we reduce the dilution about 50 per cent. But the dilution in itself is not the serious factor that the water content is. The results of our present practice have been very encouraging.

In regard to a lubricating oil and the question of changing oil, the waste has been considered; but we find that, with a ventilating system and the reduction in dilution, when we have over-dilution due to cold operation, short runs and so on, the viscosity of the oil will actually change for the better on more continuous runs. The dilution will follow the seasons to a certain extent. As the weather gets warmer, it will become less. The condition of the oil then will automatically follow the operation of the engine if the operation is consistent. This means that oil can be used for a longer period if you do not consider the dirt and ash that are picked up through the engine, the quantity of dirt and ash varying with the different types of inlet, carbureter or cleaner. If a cleaner is attached to the oil system to take out what dirt gets into the oil, we consider that we can tell our customers to change oil after 2000 miles. In other words, that is improving on oil consumption by four times what the old practice used to be.

CHAIRMAN MOUGEY:—In reply to the question asked by Mr. Winchester, I would say that the Society and the Bureau of Standards have done considerable control work, studying each of these various factors for a number of years. As Mr. Strickland pointed out, the different automobile companies have also tried to do that control work in connection with their own cars. The purpose of this survey was to try to find out what the industry in general is doing on these different items and where the base-line is in the industry in general on cars of all makes and under all conditions.

I have a question that has been submitted in writing. Did the sulphur in the engine oil have any effect on corrosion? That is in the oil, not the fuel.

MR. BURKHARDT:—The quantity of fuel burned, as compared to the quantity of oil, is great. The percentage of sulphur in the oil, inasmuch as a small part only

²¹ M.S.A.E.—Assistant chief engineer, Cadillac Motor Car Co., Detroit.

of it burns, does not seem to cause any difficulty; at least this is the preponderating opinion of those who have studied the question.

Referring to what Mr. Winchester had to say, so far as the Society is concerned, studying the oil contamination question far more intimately than has been done in the survey that was carried on would of course be most desirable.

Collecting 500 or 600 samples from service stations to be checked with no trained staff and imposing upon them conditions that would be difficult enough for an experimental department to follow is a problem.

MR. WINCHESTER:—I believe that the majority of the automobile builders in the Country had secured long ago most of the material presented in this paper from their own observations in their experimental laboratories. They had to do that to conserve the general welfare of their product. The man who does not know is usually the man who buys the product. If the survey were conducted along a little different line, among the people operating the vehicles, and samples were collected from them so as to let those men have information as to how this or that device is working, the difficulty which Mr. Burkhardt has had in collecting samples will not be encountered. We should realize that many operators are seeking for enlightenment on the problems related to such a study. The result of their assistance should be conclusive information, as they could see that the tests were run on a given set of vehicles for which they are keeping accurate comparative records. No doubt we have many members who would be glad to assist in a co-operative research of this kind.

RALPH H. SHERRY²²:—As to changing oil every 500 miles, some years ago I made a survey among a number of engineers on that subject. A few of them maintained that they followed this practice the year round. About half said that they found no dilution or water troubles in summer time. They simply loaded up with oil and went on. Of course, we all know that dilution is greater in winter time than in the summer. I think that a study could be made along this line so that the general public would get information more quickly than they are getting it now as to the quantity of oil to be thrown away, as Mr. Burkhardt mentioned in his paper.

MR. BURKHARDT:—I meant to bring that out in the paper. We desire to differentiate between what comes from abrasion and what comes from corrosion. We must bear in mind that we have no samples that are distinctively representative of wear alone or of corrosion alone. Moreover, our analysis cannot be considered quantitative because we do not have the contaminants that segregated out in the form of sludge. We can merely expect that, inasmuch as all the samples were used for a constant period and approximately for the same number of miles, this segregation was the same for all samples.

GEORGE A. ROUND²³:—I do not fully agree with Mr. Winchester's suggestion that samples be sent in from fleets, because after all fleets are generally pretty carefully supervised; they do not represent the conditions that the average man encounters. I feel that the samples should be taken from the field under as widely varied conditions as possible. I also appreciate Mr. Burkhardt's remarks with respect to difficulties in getting

samples. We have had troubles enough in our own organization getting samples from other people's cars through our own engineers. When the description of the sample gets to headquarters, it is perhaps somewhat warped. Nevertheless, that is the type of samples we like to see. We have probably 1 per cent of what Mr. Burkhardt has in the line of samples, but we will give him the information we have and enable him to fill out some of the missing points in those curves.

I think I can answer the question that has been raised with regard to sulphur in the oil causing corrosion. We ran a rather careful series of tests last year and developed the relative effect of varying quantities of sulphur in the fuel and in the oil. So far as we could find, the possible variation of sulphur-content of lubricating oil had absolutely no effect on corrosion. When we stop to think that the quantity of oil passing through the engine is about 1/30, or less, of that of the fuel, the reason is very easy to see. We found that, if the sulphur-content in the fuel was high we could get indications of corrosion even in an engine running hot enough practically to eliminate any possibility of water in the crankcase.

MAX BACHEM²⁴:—The paper Mr. Burkhardt has presented is too voluminous to grasp in detail offhand, but I think that considerable valuable information is contained in it. The opportunity to study the paper and use it as a yardstick in a comparison with information we individually may have will be of considerable value.

I can readily appreciate the viewpoint that Mr. Winchester has advanced and, while I do not think he needs any defense, I believe that he has the basis of an excellent idea.

As Mr. Round stated, the survey, as it has been made, has considerable value in that it indicates conditions as they are where operation is not controlled except as this may be done by the individual's ability. The statistical method of this survey has been adopted, as I understand it, to average out the differences that occur in individual abilities.

I believe, however, that if conditions were right in a survey, which as Mr. Winchester has suggested should be conducted in collaboration with organizations that have adequate facilities, a proper conception of the problem might be obtained and by approaching it from a sympathetic standpoint out of such a survey might come an alternate set of conditions that would possibly give us some indication of the relative value of devices which are placed on the engine to enable it to operate under the conditions to which it is subjected in the individual's hands and under the conditions existing when it is being cared for by an organized, systematic and, without being at all sarcastic or derogatory to the individual, an intelligent method.

I think that we might learn in this comparison that the combating of the evils with which we have been faced in recent years has tended toward undue increased complication of the mechanism. Mr. Burkhardt broached the subject of the economics of the situation from the standpoint of the excessive use of lubricating oil. I believe that the cost of attaching devices and maintaining them is also another economic side. If we could define intelligent and systematic control of the engine, with or without these devices, it might be of some economic value, if not to the whole industry, at least to what will be increasingly a larger portion of our industry, the operation of relatively large fleets of vehicles in commercial service, both passenger and freight-carrying.

²² M.S.A.E.—Consulting metallurgical and industrial engineer. Evanston, Ill.

²³ M.S.A.E.—Assistant chief of the engineering division, automotive department, Vacuum Oil Co., New York City.

²⁴ A.S.A.E.—Max Bachem Sales Co., Detroit.

Standardization of Motorcoach Equipment and 100-Per Cent Maintenance

By G. T. SEELY¹

TRANSPORTATION AND SERVICE MEETING PAPER

ABSTRACT

MOTORCOACH operation can no longer be considered an experiment; that it is a necessity and not a temporary makeshift has been proved conclusively. Its continued success will depend on the establishment of standards of equipment and of maintenance comparable to those of the finest steam-railroad and electric-railway practice. The novelty of motorcoach operation and the comparative inexperience of the operating officials have, in many cases, resulted in slipshod methods of operation, equipment composed of many makes of vehicle of varied sizes and types and standards of maintenance that are woefully low. Reasons of policy are frequently the cause of the purchase of several makes of motorcoach for use in the same system, but the advantages of limiting the types to those that give the best satisfaction, cost the least to maintain and have the fewest failures are obvious. The effects of non-standardization of equipment are far reaching and affect not only the costs of maintenance and operation but the efficiency of the maintenance, the efficiency of the service rendered and the passenger revenue. A variegated assortment of motorcoaches not only produces a bad appearance but necessitates a supply of repair parts for each type of vehicle and decreases the efficiency of the mechanical force. Special requirements in the purchasing of special types of chassis and of bodies also result in an increase of the cost of the motorcoach and, usually, a delay in its delivery.

A high degree of maintenance costs more per mile over a short period than does slipshod maintenance, but in the long run, when both maintenance and depreciation are considered, the high degree of maintenance will be found to be cheaper. If an attractive motorcoach attracts one more passenger every two trips than a less attractive vehicle, the difference in their earning power will more than pay for the higher standard of maintenance.

The methods of inspection and maintenance used by the Chicago Motor Coach Co. are cited and described, not because they are considered to be models but because many of the features in use are the result of many years of motorcoach operation in England and America and because every effort is made to maintain each vehicle in perfect condition. Included in this description is a list of the principal items on the general-inspection sheet to which special attention must be given.

By a system of preventive maintenance plus thorough annual overhauling, rather than one of repairs after failure, the author contends that a greater percentage of motorcoaches can be kept in service, the number of spare or reserve vehicles can be reduced to the minimum, obsolescence can be retarded, fixtures and accessories can be replaced at small expense by others of better design and more reliable type and minor body changes can be made that will keep the motorcoach up-to-date and prolong and insure its maximum life.

A SURVEY of a large number of motorcoach installations in various parts of the Country leads to the conclusion that, in the present stage of motorcoach development, two very important considerations are (a) the standardization of equipment on the

smallest possible number of types and makes and (b) the establishment of a standard of maintenance that is as nearly perfect as possible.

The pioneering days of motor-bus operation are practically over and, at the present time, the locations in which new motorcoach installations can be made are few. Nearly all the centers of population, including even the smaller cities and towns, are connected either by hard-surface roads or by roads sufficiently good to allow motorcoach operation. Over practically all these roads motorcoaches now operate. The vehicles vary from small 8, 10 and 12 passenger cars to the larger and more modern de luxe parlor-cars. In nearly every city, motorcoaches of the street-car type are now in operation.

The principal course of development of motorcoach operation henceforth will be the merging of small systems conducted by individuals or small companies into larger systems, the growth of existing systems, as the territories through which the lines are operated become developed, and the replacement, in many instances, of unprofitable electric-railway and steam-railroad passenger-service by that of motorcoaches.

Motorcoach operation can no longer be considered an experiment; that it is a necessity and not a temporary makeshift has been proved conclusively. Its continued success will be dependent on the establishment of standards of equipment and of maintenance comparable to those of the finest steam-railroad and electric-railway practice. The motorcoach industry is so new and has, in many cases, been carried on by individuals so inexperienced either in transportation or along mechanical lines, that standards of mechanical operating and maintenance practice have not been generally adopted and no large body of experienced men has been developed, as has been the case with steam and electric railways. The result is that many systems are operated in a slipshod unbusiness-like manner, the equipment of some installations is composed of many makes of motorcoach of varying sizes and types and the standard of maintenance is woefully low.

ADVANTAGES OF STANDARDIZING ON ONE TYPE OF EQUIPMENT

A few weeks ago, the superintendent of equipment of a large company visited the shops of a public-utility organization that operated 20 motorcoaches of various makes. After inspecting the equipment and shops, the manager of the public-utility company asked the superintendent if he had any suggestions to make. The superintendent replied:

Yes, standardization. You have told me that you know what make and what type of motorcoach give the best satisfaction, cost the least to maintain and have the fewest failures, yet, a short time ago, you purchased two motorcoaches of an entirely different make from those you were then operating. You are now operating five different makes in a small fleet. What was the reason for the purchase of a different type?

The manager replied:

Policy and the necessity for obtaining two additional motorcoaches practically overnight.

¹ Vice-president, Chicago Motor Coach Co., Chicago.

The same situation obtains in the majority of motorcoach installations made by public-utility companies throughout the Country. In one large initial installation of motorcoaches, the operating officials, after a careful investigation, recommended one certain type of vehicle, yet, for reasons of policy, the executives purchased several different makes. After a year or two of operation, results showed that the judgment of the operating officials was correct, and that a large investment has been made in motorcoaches that were not suited to the requirements of the service.

From my observation, I believe that standardization is not considered in 75 per cent of the purchases of motorcoach equipment. I have seen examples of as many as eight different makes in fleets of from 100 to 200 motorcoaches; and this variety was not caused by the acquisition of operating companies but by the direct purchase of new equipment. The decision as to the make of motorcoach to be purchased is made, in many instances, by the financial heads, because of interlocking directorates, power customers, freight consignments by big manufacturers, political favors performed by local representatives of manufacturers, acceptance of stock in payment for commissions, and similar reasons.

EFFECT OF NON-STANDARDIZATION

The effect of non-standardization is far-reaching and affects not only the costs of maintenance and operation, but the efficiency of maintenance, the efficiency of the service rendered and the passenger revenue.

A variegated assortment of motorcoaches on a line produces a bad appearance. Passengers naturally prefer one type of vehicle to another and are dissatisfied if they must use the poorer motorcoaches or wait until the vehicle they prefer reaches them.

One operator of a de luxe motorcoach line has equipment that has proved unsatisfactory and, because of lack of standardization, is obliged to run city-type motorcoaches of another make on this line. Many patrons prefer the city type of motorcoach to an unsatisfactory de luxe type. The result has been such dissatisfaction with the equipment on the part of the public that traffic has been materially reduced.

Assume that a company is operating 100 motorcoaches of 6 different makes from 3 garages. One garage is not likely to house motorcoaches that are exclusively of one kind. As many as three types may be in the same garage. This necessitates a supply of repair parts for each type of motorcoach. In the main repair-shop, a complete stock of parts for all six makes must be carried. Unless a large amount of money is invested in a complete stock of parts for each type of equipment, the storekeeper will keep in stock only such parts as are used most often. Sometimes motorcoaches will be kept in the garage for several weeks awaiting some replacement part that is not in stock. If the entire fleet is of one make, a complete stock of parts can be kept, including such parts as fail only occasionally, the value of the inventory is maintained at the minimum and motorcoaches can be repaired and returned to service promptly.

USE OF SINGLE TYPE OF MOTORCOACH INCREASES EFFICIENCY

The efficiency of the mechanical force is greatly increased if one type of motorcoach is used. Men become more proficient when they continually do the same thing; and special tools are devised to expedite the removal and the replacement of certain parts. Each make of motorcoach has its peculiar difficulties. Familiarity with the

work enables a man to make repairs more quickly and also to foresee and obviate failures.

That the most dependable type of motorcoach should be favored and better cared for and that the poorer type should be neglected is only natural. Men repairing the poorer motorcoach become discouraged, and the efficiency and morale of the whole department are lowered. Difficulties are magnified. The whole organization becomes imbued with the idea that one particular type of motorcoach is not good, whereas the fact may be that if the attention of the maintenance force were directed to it, this type of vehicle would operate satisfactorily. The effect on the operating personnel is an important feature when a number of types of motorcoach are in operation. Drivers naturally prefer the better types of equipment. If they are obliged to use a type they do not like, they report imaginary difficulties and turn the vehicle in for insignificant defects, so that they will not be obliged to operate it. The facts mentioned will be evident to any operating man who studies his own installation of motorcoaches or those of neighboring companies.

A careful study should be made by each company to determine the type of motorcoach that gives the best satisfaction under its own operating conditions. After a selection has been made, additional vehicles should be of the same type. The number of motorcoaches in reserve over and above those required for actual operating schedules should be sufficient not only to maintain the equipment properly but also to meet any sudden demand for increased service so that it will not be necessary, in emergencies, to purchase any type of equipment that can be picked up immediately. The type of motorcoach that can be secured overnight is usually one that is not satisfactory and for that reason can be acquired quickly.

METHODS OF THE CHICAGO MOTOR COACH CO.

The Chicago Motor Coach Co. makes every effort to standardize its equipment and, at present, on 415 motorcoaches, a single type of Knight sleeve-valve engine is used, although there are three different types of chassis. On two of the types, the method of suspension of the engines is being changed, as the motorcoaches pass through the general repair-shop, so that within a short time all the engines will be interchangeable.

When the present company purchased the original operating-company, it took over a number of motorcoaches on which the chassis were unsatisfactory. The frame was so weak that the bodies were being destroyed by excessive weaving. The riding qualities were poor and passengers were continually complaining and calling attention to the better riding-qualities of other motorcoaches. The seating arrangement also was poor.

These chassis are now being remodeled. A more rigid frame and new springs, radiators, hoods, and fenders are being installed. The shape of the front end of the body and the seating arrangement are being changed to conform to the standard equipment. The result is a rebuilt vehicle that is similar in appearance and riding quality to a standard motorcoach and having practically the same types of unit. The numbering of the motorcoach has been changed, so that the old "300" class, which was disliked by the public will disappear in a few months. The cost of the rebuilding was not excessive, and the result is a good operating vehicle that is practically standard with the other equipment; it will have many more years of life than if it had not been rebuilt and its earning power has been increased.

Standardization is a subject of vital importance to the builder. Most purchases of coaches are made in small

quantities of 1, 2, 5, or 10. Many purchasers desire changes in the chassis or the body design, principally the latter, because of some local condition. If these changes are made, the result will be an increase in the cost of the motorcoach and, usually, a considerable delay in delivery.

Up to the present time, the development of motorcoach design has been rapid, keeping pace with the development of operation and embracing all the phases of city and inter-city operating-conditions. Builders, by a careful study of the demands of their customers and of the various requirements of State regulatory bodies, probably could establish standards that would meet practically all conditions. The operator could then standardize his equipment in conformity with the standards of the builder, secure the advantages accruing to him through lower cost and quick delivery and be assured of being able to maintain a uniform type of equipment for his entire system that would assure him the benefits to which reference has already been made.

100-PER CENT MAINTENANCE

A passenger in a steam-railroad train or on a well-conducted street or interurban electric-railway system rarely sees a vehicle that gives indication of not being in perfect operating-condition. On the other hand, a large number of motorcoaches in operation at present are in poor condition. Two instances may be cited that have come under my observation.

Recently in a large city a motorbus stopped at the curb. It evidently had not been painted for 2 or 3 years. The body was full of dents, scratches along the sides showed the metal beneath the paint, one window was broken, the hooks holding down the hood were missing, the hood was partly open, the glass in the door was cracked, and below the door a large cleat of wood was hanging suspended from a wire that the cleat was supposed to hold in place.

Later, I rode on an inter-city motorcoach that was very comfortable and easy-riding, but the windows, having become loose, made such a noise that conversation was impossible. Rain began to fall and, as the window could not be raised, I was obliged to change my seat. Both these companies operate many cars and motorcoaches and should realize the importance of attractive well-maintained equipment.

A high degree of maintenance of well-painted and clean motorcoaches costs more per mile over a short period than does slipshod maintenance but, in the long run, when both maintenance and depreciation are considered, the high degree of maintenance will be cheaper.

ATTRACTIVE APPEARANCE INCREASES TRAFFIC

From the point of view of traffic, if a more attractive motorcoach attracts one more passenger every two trips than a less attractive vehicle, their difference in earning power will more than pay for the higher standard of maintenance. The reasons seem elemental and obvious. Because they are overlooked in so many cases and because the results of a motorcoach operation may be determined by these factors, some of the reasons for adequate maintenance will be discussed.

The methods used by the Chicago Motor Coach Co. will be cited, not because we consider our practice a model, or claim to maintain our motorcoaches in perfect condition, but because many of the features in use are the result of many years of motorcoach operation in England and America and every effort is made to maintain each coach in perfect condition.

Of the 415 motorcoaches owned by the Chicago Motor Coach Co., 364 are of the double-deck type, and 51 of the single-deck type. After a number of the older type of chassis have been reconstructed, all the chassis, except 10 of the New York City so-called L type, will be practically of one standard, having the same types of spring, engine, clutch, transmission, rear axle, and the like.

All operation is of the city-service type and involves many stops per mile in dense traffic. A central repair-shop is maintained, to which each motorcoach is brought once a year for painting. Very little work on the chassis is done at this time as the units are replaced in the operating garages whenever they have reached their average life, which is determined from experience. As the life of the various units does not coincide with the period of repainting, to replace all the units on a fixed-time basis, such as 1 year, would be uneconomical. In the central repair-shop, repairs are made to the various units, such as the engines, transmissions, clutches, brake-linings, and the like.

DISTRIBUTION OF MAINTENANCE

Fifteen motorcoaches are usually in the central repair-shop at one time. The remaining 400 vehicles are distributed among 4 operating-garages located at the most convenient point for storage in each division of the city. In each operating-garage is kept a full supply of small repair-parts and spare units, such as engines, transmissions, clutches, rear-axle springs, and the like. The only tools in each operating-garage consist of a wheel-press, small hand-drill, emery wheel, arbor-press, small portable crane for removing the engine, and hand-tools.

During the interim between the annual repainting, all the work necessary to keep the coaches in 100-per cent operating condition is performed at the operating-garage except major body-repairs necessitated by accidents. A brief outline of the work performed in the garages is as follows.

In each motorcoach is kept a daily motorcoach-report on which the driver enters any defect that was noticeable during the time he was driving the vehicle. These cards are turned in by the driver when the motorcoach returns to the garage, and the necessary repairs are made by the day or the night mechanical force. Notations of such repair-work are made on an individual general-inspection sheet for each motorcoach and include the date, the nature of the work done and by whom the repairs were made.

Each motorcoach is given a general inspection every 2800 miles. The general-inspection sheet is placed in the motorcoach so that the mechanic making the inspection has a complete log of every failure or defect that has occurred since the last general inspection and of what has been done to remedy the trouble.

The general-inspection sheet has a list of 106 separate items that must be given attention. As each item is inspected, it is checked off, a space being provided for the signature of the man making the inspection. The principal items on this inspection list are as follows:

ITEMS ON GENERAL-INSPECTION SHEET

Radiator

Examination for leaks and hose connection
Any hose not good for 2500 miles is replaced

Engine

Engine is tested for compression, is run so that it can be examined for knocks and is examined for oil leaks
Crankcase is drained and refilled with fresh oil
Exhaust ports are cleaned

Fan and fan-belt are inspected and greased

Ignition

Magneto is thoroughly cleaned
Breaker points are adjusted
Magneto is oiled
Lead wires are examined
Spark-plugs are examined and adjusted
Installing-switch is examined

Carbureter

Jets are removed from the carbureter and are cleaned
Float and float weights are examined
Pull-back spring on throttle-rod is examined for wear
Accelerator and cross-shaft are oiled
Gasoline-tank and the gasoline line are examined for leaks
Sediment bowl is drained

Clutch

Clutch linings are examined through inspection holes
Clutch must be properly adjusted

Transmission

Transmission is examined for noise and for oil leaks
Suspension bolts are examined
All gears must mesh properly

Rear Propeller-Shaft

All bolts must be tight with no undue play
Joints must be properly lubricated

Rear Axle and Brakes

Both sides are jacked up to see that the wheels turn freely
Wheel bearings are tested for end-play
Wheels are removed and the brake-linings inspected
Tires are examined for flat spots and for tightness on taper
Brake-drum bolts must be tight
Carrier bolts are examined for leaks and tightness
Oil level is examined
Worm and wheel are examined for wear
Flange must be tight on the worm-shaft
Rear-spring bolts are tightened
Rear spring is examined for broken leaves

Front Axle, Steering and Front Springs

Front-spring clips must be tight
Front wheels are jacked up and the bearings are tested for wear
Front-wheel bearings are greased
Tires are examined
Wheels must be in line
Tie-rods are examined to see that they are tight in taper
Front springs are examined for broken leaves
Tie-rod connections are examined
Tie-rod connections are greased
Drag-link is examined
Drag-link connections are greased
Steering drop-lever is examined
Pivot pins are examined and greased
Steering-gear is greased
Steering-gear bracket must be tight on the frame
All important nuts are pinned
Steering-gear-column tube must be tight
No unnecessary play is allowable

Electrical

At every fourth inspection, the generator is removed
The generator bearings are lubricated and the generator output checked
Wearing parts must be in good condition and all connections tight
Battery is examined
Lights are examined and the lamps cleaned
Driver's and conductor's bells are examined
Bells and buzzers are examined
Connections in the junction-box must be kept tight

Body

Interior of motorcoach, including seats, is washed at every inspection-period

Loose seats and rattling windows are looked for

Entire motorcoach is examined for any projections that are liable to tear passengers' clothing
Heating-pipe covering and screws must be tight
Stairway hand-rails are examined, wheels are painted at every general-inspection period and the engine bonnet and fenders every 5000 miles
Fire-extinguisher is examined

REPLACEMENT OF UNITS

If, on general inspection, any unit is found that is not in condition to operate satisfactorily until the next general inspection, a spare unit is taken from the storeroom and installed in the motorcoach. The defective unit is sent to the central repair-shop for repairs and, after being put into perfect condition, is returned to the storeroom.

Sixteen motorcoaches undergo general inspection each day, eight of which are withheld from the morning run so that work can begin at 7:30 a.m. The other eight are brought in after the morning rush-hour. The traffic peak in the morning rush is less pronounced than in the evening, so that eight motorcoaches can be made available for repairs without affecting the service.

All inspection work must be completed by 4:30 p.m. so that all motorcoaches will be available for the evening rush-hour service. If any defect develops in any motorcoach during the day and the vehicle is brought to the operating-garage before 2:00 p.m., the repairs can be completed and the motorcoach sent out for service during the evening rush.

Between the general inspections, motorcoaches are inspected at night for the following purposes:

Once a week, the differential and transmissions are examined for grease
The steering-gear is examined
The batteries are filled every 7 days
The brake adjustment is checked

One of the important features of design that enables repair-work to be done readily is the fact that each unit of the chassis is independent of the other units and can be replaced in the minimum of time. For example, the average time required to make replacements is shown in Table 1.

TABLE 1—AVERAGE TIME REQUIRED TO MAKE REPLACEMENTS

Name of Part	Number of Men	Time Required, Min.
Front Spring	1	30
Rear Spring	1	60
Rear-Axle Shaft	1	90
Transmission	2	45
Clutch	1	30
Engine	2	150
Radiator	2	30
Generator	1	15
Battery	1	15
Removing and Replacing Differential	2	150

A card-index for each unit is maintained at the central repair-shop. A serial number is stamped on each engine, clutch, transmission, rear axle, and the like. On the card for each unit is shown the date of the installation of the unit in the motorcoach, the number of the motorcoach, the date the unit is removed, and the nature of the work done. In this way, the performance of each individual unit and of the units as a whole can be studied.

The result of this system is that, on an average, 99.5 per cent of the 400 motorcoaches in the operating-

garages are available for service every evening during the rush-hour. In other words, in all the operating-garages, not more than two motorcoaches on an average, and on many evenings not a single vehicle on the entire system, are out of service during the evening rush-hour, with the exception of those motorcoaches in the central repair-shop.

The whole system of inspection and maintenance is based on the principle of preventive maintenance, instead of repair after failure. The period of 2800 miles between inspections has been fixed by experience as being perfectly safe and, in our opinion, might safely be increased to 3000 or 3200 miles, provided lubrication is taken care of between the inspection periods.

RESULTS OF PROPER MAINTENANCE

Lower total maintenance-costs over a period of years will be brought about by proper preventive maintenance. If a certain unit is neglected and allowed to fail in service, the resulting total cost of repairing the damage may be many times the cost of replacing the necessary part during inspection.

Greater reliability in service will follow preventive maintenance. There is no reason that motorcoach operation should not be fully as reliable as electric-railway or steam-railroad service, provided the vehicles are properly designed and properly inspected and maintained. Motorcoaches present a better appearance if, at each

inspection, the scratches in the body are touched up with paint, and the wheels, the fenders, and the under body parts are painted at regular intervals. With proper preventive maintenance, accidents due to defective equipment will be practically unknown.

As outlined above, a greater percentage of motorcoaches can be kept in service and the number of spare or reserve vehicles required can be reduced to the minimum if major failures are prevented. Obsolescence may be retarded by proper maintenance. When motorcoaches are brought into the repair-shop for yearly painting, fixtures and accessories can often be replaced at a small expense by others of a better design or a more reliable type. Minor body changes can be made, seats replaced or seating arrangements changed, making the motorcoach more up-to-date and prolonging its life many years. In most cases, this can be done without excessive cost and, if the life of the vehicle is increased from 150,000 or 200,000 to 300,000 miles, the resulting decrease in depreciation charges will be many times greater than the cost of the changes, besides frequently reducing the maintenance cost further.

If motorcoach operation is to be on a sound economic basis, the life of the vehicle must be from 8 to 10 years or even longer. Preventive maintenance plus thorough annual overhauling and bringing every feature possible up-to-date will assure the maximum life of a properly designed vehicle.

IRON AND STEEL EXPORTS AND IMPORTS

IN most branches of the American iron and steel trade, the European market is relatively unimportant. In the last fiscal year exports of iron and steel in all forms from the United States had a value of \$238,245,744. Of this total, \$78,541,609 consisted of advanced manufactures, such as cutlery, tools, hardware, and the like, and \$2,633,014 of iron ore, leaving only \$77,344,096 of semi-manufactures and \$79,727,025 of steel-mill products. In these groups the most important items were 692,370,544 lb. of iron and steel sheets, of which only 32,319,893 lb., or 4.7 per cent, was exported to Europe; and 407,564,167 lb. of tin plate, of which 39,505,648 lb., or 9.7 per cent, went to Europe. In the case of other products the proportions shipped to Europe were less.

Because of existing freight rates, the danger of penetration of foreign steel into our interior markets in large vol-

ume is very remote. Of the \$44,350,750 of iron and steel imported into this Country in the last fiscal year, \$5,433,534 consisted of iron ore and concentrates, \$10,179,735 of pig iron and scrap and \$6,162,360 of advanced manufactures, leaving only \$22,575,121 of products competing directly with the output of domestic mills. Generally speaking, the quality of European steel is not comparable with that of the American product. While some very high-grade steel is produced abroad, whether it could compete in price with our own to any considerable extent, particularly if the operations of the European trust should result in a material advance in prices of European steel is doubtful. Moreover, the possibility of an increase in import duties to counteract any serious threat of invasion of American markets always calls for consideration.—*Guaranty Survey*.

GERMANY

ALTHOUGH Balfour called her the greatest of all international debtors, Germany is nevertheless the most nearly prosperous country in Europe today. Competent foreign observers claim that her normal industrial capacity is one-eighth to one-quarter greater than before the war. By normal capacity they mean effective capacity to produce goods at a profit in competition with other countries. Dr. Julius Hirsch, professor of economics at Berlin University, says the population has increased 3,500,000 since 1919. The number engaged in industry is 33,000,000, whereas, from the loss of territory, it should only be 27,000,000. For every 100 km. (62.137 miles) of railway in 1913 there were 48 locomotives, now there are 56; and more passenger and

freight-cars. In 1925, the number of passengers carried was 70 per cent more than in 1913, and the number of miles they traveled was nearly double.

The savings-bank situation there is another favorable index. The savings banks were empty when inflation of the mark currency stopped. The people had drawn out all their money to convert it into something or anything more valuable than printed paper. When stabilization came savings began again. In 2 years, according to Garet Garrett in *The Saturday Evening Post*, savings-bank deposits rose to the sum of 2,000,000,000 gold marks and that was one-tenth of all that had ever been saved in savings banks up to the beginning of the war.—*Backe Review*.



Applicants for Membership

The applications for membership received between Oct. 15 and Nov. 15, 1926, are given below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

ALCORN, W. C., manager and vice-president, American Swiss Magneto Co., *Toledo*.

BABOR, RUD J., chemical engineer, Ethyl Gasoline Corporation, *New York City*.

BALL, VERNON W., service correspondence, General Motors Truck Co., *Pontiac, Mich.*

BARNARD, JOHN F., chief engineer, U. S. Industrial Alcohol Co., *Curtis Bay, Md.*

BRECHT, AUGUST F., draftsman, General Motors Corporation Research Laboratories, *Detroit*.

BROWN, OTTO W., sales engineer and manager, Wisconsin Machinery & Mfg. Co., *Milwaukee*.

BUEHLER, LOUIS C., factory manager, Indianapolis Tool & Mfg. Co., *Indianapolis*.

BURGESS, C. M., president, Burgess-Norton Mfg. Co., *Geneva, Ill.*

CHAMBERLAIN, R. N., research engineer, Gould Storage Battery Co., *New York City*.

CHRISTMAN, R. W., charge of experimental department, Oakland Motor Car Co., *Pontiac, Mich.*

CLAUSEN, H., manager of lubricating department, American Oil Co., *Baltimore*.

COFFEY, PAUL E., clerk to the superintendent of garages, Montreal Tramways Co., *Montreal, Que., Canada*.

CORRADO, VINCENT A., chief engineer, Motors Metal Mfg. Co., *Detroit*.

DANIELS, H. T., manager and buyer, S. W. Grove Parts Co., *Enid, Okla.*

DAVIS, LLOYD L., chief chemist and chief engineer, Pierce Petroleum Corporation, *St. Louis*.

DAVISSON, D. W., automotive superintendent, Shell Co., *Los Angeles*.

DRISSENER, ALFRED E., chief engineer, National Acme Co., *Cleveland*.

DROBIG, LEO, manager of technical department, Transport Motor Co., *Spokane, Wash.*

DRURY, THOMAS W., chief engineer, Westinghouse Electric & Mfg. Co., *East Pittsburgh, Pa.*

DUNWOODY, HALSEY, vice-president, Gardner Motor Co., *St. Louis*.

GENIESSE, J. C., research chemical engineer, Atlantic Refining Co., *Philadelphia*.

GREBE, CHARLES F., JR., superintendent, Milwaukee Die Casting Co., *Milwaukee*.

GULBRANSEN, J. G., mechanic, Troy Motor Co. of Southern California, *Los Angeles*.

HAINES, HAROLD W., manager of chemical sales, New York division of U. S. Industrial Alcohol Co., *New York City*.

HALPIN, ROBERT A., charge of factory standards, Yellow Truck & Coach Mfg. Co., *Chicago*.

HAPPEBSBERG, HERBERT, general manager, Garford Motor Truck Co., *Long Island City, N. Y.*

HAZELHURST, GEORGE, JR., superintendent, Shawsheen Garages, Inc., *Andover, Mass.*

HELMS, WALTER, service and salesman, Four Wheel Drive Auto Co., *Clintonville, Wis.*

HEM, HALVOR WARREN, engineer, Toledo Scale Co., *Toledo*.

HEWINS, I. G., sales manager, Van Dorn & Dutton, *Cleveland*.

HOERNES, H., 109-99 Garden Avenue, *Jamaica, N. Y.*

HOLMES, J. R., experimental and research engineer, Chandler Motor Car Co., *Cleveland*.

HORTON, F. N., sales manager, John Morrow Screw & Nut Co., Ltd., *Ingersoll, Ont., Canada*.

HORTON, WILLIAM M., JR., factory manager, Lamson-Sessions Co., *Cleveland*.

HOTCHKISS, GROSVENOR, engineer, Western Union Telegraph Co., *New York City*.

HOWE, A. VANCE, automotive inspector, Westinghouse Air Brake Co., *Boston*.

HURLEY, ROY T., general manager and chief engineer, B. G. Corporation, *New York City*.

JACKLIN, JOHN R., used car appraiser, Reo Motor Car Co. of New York, Inc., *New York City*.

JACKSON, S. B., sales engineer, General Electric Co., *Detroit*.

JOHNSON, A. M., special representative, Hutto Engineering Co., *Detroit*.

KETTINGER, C. G., sales manager, Wadhams Oil Co., *Milwaukee*.

KLEIN, WILLIAM F., coach division engineer, Yellow Truck & Coach Mfg. Co., *Pontiac, Mich.*

KRAMER, HERMAN C., master mechanic, Stutz Motor Car Co. of America, Inc., *Indianapolis*.

KURT, FRANKLIN T., student, Massachusetts Institute of Technology, *Cambridge, Mass.*

LANPHER, MAJOR THOMAS G., Air Service, Selfridge Field, *Mount Clemens, Mich.*

LARGE, S. ROBERT, assistant chief engineer, New Departure Mfg. Co., *Bristol, Conn.*

LAUGHLIN, CAPT. EDWARD, chief engineer officer, Air Service, Wilbur Wright Field, *Dayton, Ohio*.

LEES, WALTER EDWIN, aeronautical service engineer, Packard Motor Car Co., *Detroit*.

LICHTY, LESTER C., assistant professor of mechanical engineering, Yale University, *New Haven, Conn.*

LINDSAY, W. ROGER, automotive engineer, General Motors Export Co., *New York City*.

LLOYD, EDISON W., manager of used car department, Ball Campbell Co., Ltd., *Vancouver, B. C., Canada*.

LUNDBERG, H. B., manager, Michigan Screw Co., *Lansing, Mich.*

APPLICANTS QUALIFIED

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Applicants Qualified

The following applicants have qualified for admission to the Society between Oct. 9 and Nov. 10, 1926. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff) Affiliate; (S M) Service Member; (F M) Foreign Member.

McINTYRE, DUNCAN A., owner, McIntyre Airport, Tulsa, Okla.; president, Aircraft Sales Co. of Oklahoma, Tulsa, Okla.

MAGEE, RICHARD A., sales engineer, Texas Co., New York City.

MARS, JAMES A., office of the Chief of Air Service, City of Washington.

MARSCHNER, WALTER, mechanical engineer, Atlantic Aircraft Corporation, Hasbrouck Heights, N. J.

MARTIN, MAJOR FREDERICK L., Air Service, Bolling Field, D. C.

MOREE, K. EARL, assistant chief engineer, J. I. Case Plow Works, Inc., Racine, Wis.

MURPHY, JAMES E., service manager, Semmes Motor Co., City of Washington.

POOS, WILLIAM L., sales engineer, Cleveland Graphite Bronze Co., Cleveland.

PRESTON, EDWIN L., commercial aviator, Lovejoy Aviation Co., Flint, Mich.

PRITCHARD, W. S., experimental engineer, Motor Products Corporation, Detroit.

PURVIN, BENJAMIN R., manager, Vibro Insulator Co., Worcester, Mass.

RAYMOND, L. R., sales engineer, Moreland Sales Corporation, Oakland, Cal.

REED, GEORGE R., chief engineer of the Chicago division of C. G. Spring & Bumper Co. of Illinois, Chicago.

REYNOLDS, RAY, service manager, H. J. Edwards, Inc., San Diego, Cal.

ROSE, RAYMOND HUGH, automotive engineer, Guy Motors, Ltd., Wolverhampton, England.

SCHAEFLE, A. J., manager of parts and service, Olds Motor Works, Denver.

SCHOLZ, W., technical director, Reichsverband der Automobilindustrie, Berlin W. 8, Germany.

SCHUBERT, FRANK R., vice-president, McGill Metal Co., Valparaiso, Ind.

SMITH, W. McPHERSON, secretary-treasurer and general manager, Spencer-Smith Machine Co., Howell, Mich.

SWALM, ROBERT A., treasurer and manager, Schuylkill Motors Co. and Schuylkill Motors Transportation Co., Pottsville, Pa.

TANNER, HUBERT D., manager of gear division, Pratt & Whitney Co., Hartford, Conn.

THOMAS, CHARLES, layout draftsman, Durant Motors, Inc., Elizabeth, N. J.

THORN, WRAY T., transportation engineer, Sanderson & Porter, New York City.

TJAARDA, JOHN, body engineer and designer, Locke & Co., Rochester, N. Y.

VANNES, R. H., superintendent of the department of public works, Montclair, N. J.

WELCH, LEON C., manager of lubricating department, Standard Oil Co. of Indiana, Chicago.

WHEELER, FREDERICK CHARLES, engineer, Sauzedde Corporation, Detroit.

WHITLOCK, L. H., manager, Whitlock Co., Wichita, Kan.

WILLARD, JOHN RODERICK, apprentice engineer, Aluminum Co. of America, Cleveland.

WILSON, GUY W., engineer, General Electric Co., Schenectady, N. Y.

ZOLLA, AMEDEE, electrical engineer, White Motor Co., Cleveland.

ARMITAGE, A. D. (M) vice-president, general manager and chairman of the board, J. H. Williams & Co., 400 Vulcan Street, Buffalo.

BAK, JOSEPH V. (M) foreman and body designer, Studebaker Corporation, South Bend, Ind.; (mail) 2402 Erskine Boulevard.

BEARD, FREDERICK WILLIAM (A) director, secretary and treasurer, General Motors, Ltd., London N. W. 9, England; (mail) Lavender Cottage, 86 Princes Park Avenue, Golders Green, London N. W. 11, England.

BEST, PERCY (M) automobile designer, Pierce-Arrow Motor Car Co., Buffalo; (mail) 47 St. Johns Place.

BISHOP, G. E. (A) president, Bishop Products Co., Cleveland; (mail) 760 Rose Building.

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VOL. XIX

NO. 6

THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS



DECEMBER 1926

TRANSPORTATION AND SERVICE MEETING NUMBER

SOCIETY OF AUTOMOTIVE ENGINEERS INC.
29 WEST 39TH STREET NEW YORK, N. Y.

Issued monthly, \$1 per copy, \$10 per year; foreign \$12 per year; to members, 50 cents per copy, \$5 per year.

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THE recoil force of a car spring is not a constant force. This force varies the same as does the recoil force of an archer's bow. Bent slightly out of its normal shape the bow recoils mildly, and so does a car spring. And each little bit more that the bow or car spring is bent means a corresponding increase in its recoil force.

Watson Stabilators are simply brakes for controlling recoil force. The reason these Watson brakes are so effective is because their resistance changes in keeping with each change in the distance the car spring has been bent from normal and hence in keeping with each variation of recoil force.

Watson Stabilators, being round and black with a tail coming out, resemble, in looks, many devices operating on the snubbing principle and are thus erroneously regarded as similar in action to these snubbing devices. As a matter of fact, however, it will be seen by the above that in principle and in operation they are exactly the opposite of snubbing devices. Stabilators are farther removed from the snubbing principle than are any other devices made in the world.

It is impossible to correctly control varying forces without employing varying resistances—resistances which are in proportion to these force variations.



Original and Sole Manufacturers of Stabilation

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[Detroit Branch: 3081-3083 Grand Boulevard, East]

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BOATS AND ENGINES
DETROIT, U. S. A.

September 22, 1926

Federal Mogul Corporation
Detroit, Michigan
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Dear Sir:

We are taking this opportunity to thank your corporation for the splendid results we have obtained from your bearings for some time past.

We wish to state at this time that the MISS AMERICA III, MISS AMERICA IV, and MISS AMERICA V were all equipped with the Federal Mogul bearings which are still there and are in as good condition as when first put in. After considerable experience with several different makes of bearings we are more than pleased to state that we can recommend your product the very highest.

We are mailing you under separate cover two photos - one of the MISS AMERICA IV and one of the MISS AMERICA V. We hope that you will accept these photos with our compliments.

Very truly yours,

GAR WOOD, INC.

W. J. Smith
General Manager

Federal-Mogul
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Bronze-Back Babbitt-Lined Bearings

Die Cast Babbitt Bearings and Bushings

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Standard equipment on every automotive vehicle where quality counts. Ask Federal-Mogul engineers to confer with you on your bearing requirements. There will be no obligation on your part.

FEDERAL-MOGUL CORPORATION
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Licensed under U. S. Patents
1,455,939; 1,302,584; 1,302,838; 1,340,337.

"Quality Bearings, Bushings and Bearing Metals for Over 25 Years"

Quality Heaters

**Stewart-Warner Quantity Production Keeps costs down and quality up.
Stewart-Warner name insures public acceptance.**

Select your heater in keeping with the public acceptance you expect for your car.

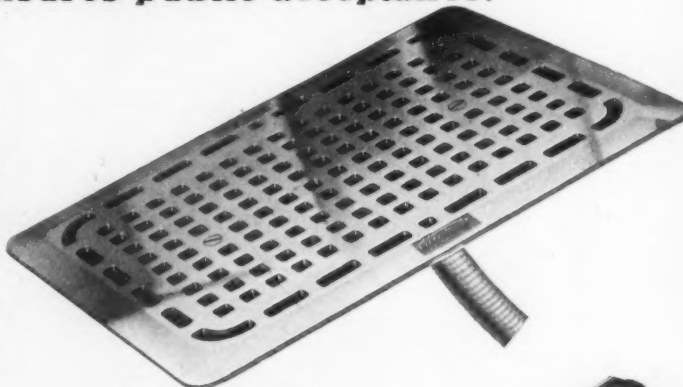
There is a Stewart-Warner Heater for every car installation, and you can rest assured that these Heaters will reflect only credit to your car, giving the car owner all and more than he expects.

Note the features which contribute to perfect performance and service: **[1] DASH CONTROLLED. [2] DRAWN STEEL HEATING UNIT. [3] UNIVERSAL VALVE. [4] DOUBLE ACTING VALVE.**

Stewart-Warner Service through approximately TWO HUNDRED Stations in key cities, is another distinct advantage in specifying Stewart-Warner Heaters and other Accessories.

Complete information upon request.

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1826 DIVERSEY PARKWAY
CHICAGO, U. S. A.



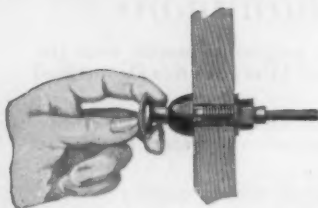
FLOOR TYPES
for ALL CARS



RAIL TYPES
for ALL CARS

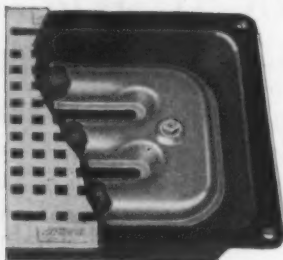
Superior Features of Stewart-Warner Heaters

**1-
Dash
Controlled!**



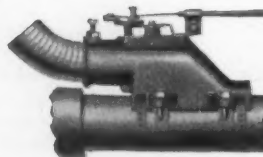
Stewart-Warner Heaters are easily operated by a convenient dash control making it possible to regulate the temperature of the car interior to a fine degree.

**2-
Quick
Heat!**



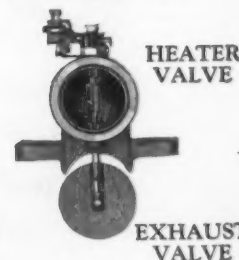
DRAWN STEEL HEATING
UNIT
That Radiates Heat Quickly

**3-
Universal
Valve!**



The Stewart-Warner Double Exhaust Valve makes possible the utilization of all the heat from the engine when the valve is open. When this valve is closed, however, it is absolutely tight. No heat can pass into the Heater. The installation is universal. This one valve fits practically all cars!

**4-
Double
Valve!**



HEATER
VALVE

EXHAUST
VALVE

The Stewart-Warner Exhaust Valve is, in reality, two valves. It has two dampers that work at right angles to each other—one closing the exhaust pipe, while the other opens the car heater intake, and vice versa.

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for better accessories



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Gained through years of refinement, and a high quality product, Kingston Accessories have enjoyed for years the confidence of some of the largest American automobile manufacturers. ✦ ✦ ✦

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Standard
Equipment on
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Standard
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Uniform operation and easy starting in winter are possible only with perfect carburetion. Tillotson gives you this performance.

TILLOTSON MANUFACTURING CO.
Toledo Ohio

"The Logical one is Tillotson."



The Gravity Type Fil-Trap
A perfect gasoline strainer with an indestructible filtering element. The ideal filter for Standard Equipment.

THE BUILDING OF A HARRISON RADIATOR

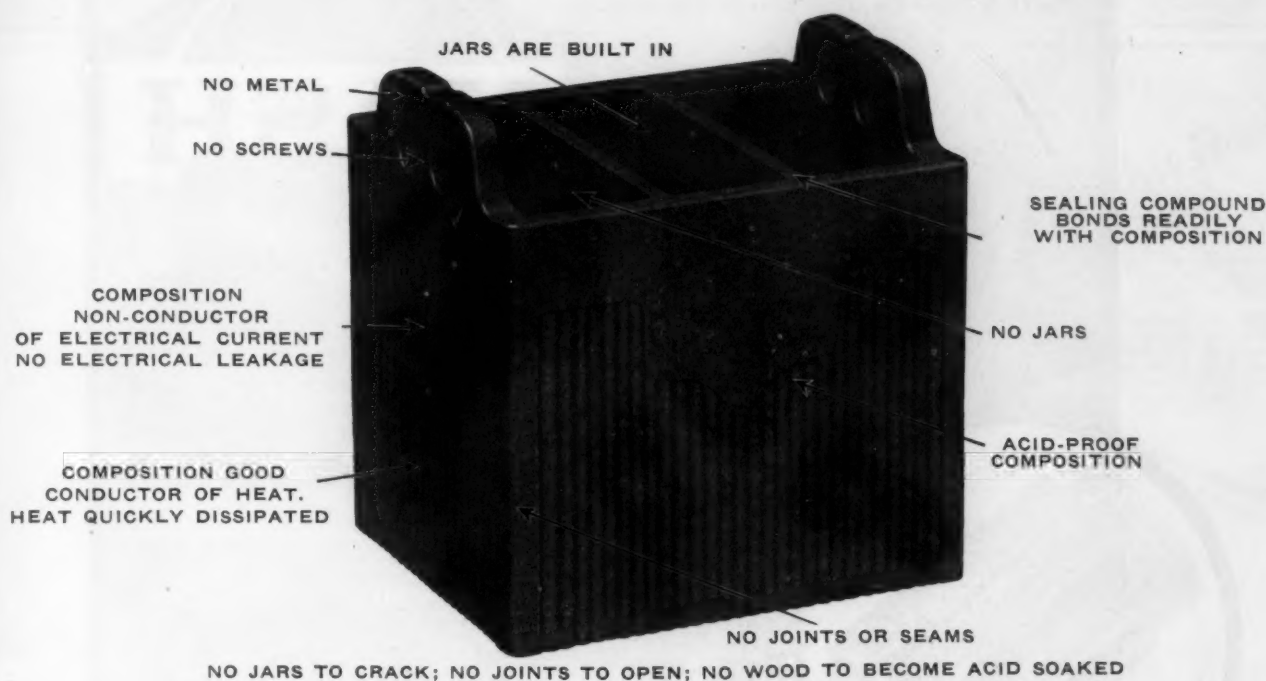
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Every Harrison Radiator is carefully tested for leaks. The core is filled with air and submerged in a tank of water. Air bubbles definitely mark the presence of the slightest leak. Once located, they are immediately soldered and made air-tight.

But this test alone is not considered sufficient by Harrison. The core is again immersed and inspected to preclude further any possibility of leakage.

Thus precautions are taken at the various stages in Harrison production to insure uniform quality and dependability.

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RADIATORS***Under-water test for leaks*



Combines jar and box in one lasting unit

The defects of wooden boxes, as you know, cause many battery failures. Because of the thoroughness with which the Richardson Improved Battery Case overcomes these defects, it is consistently used by leading battery manufacturers.

This scientific case has no joints or seams to open, no jars to crack—for it combines jar and box in one lasting unit, ready for quick assembly in the battery. The composition is acid-proof; "shorts" are

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It is a non-conductor of electrical current, and because of the similar nature of the composition sealing compound, bonds tightly and uniformly with the composition, thus preventing leakage.

Hundreds of thousands of Richardson Battery Cases are in actual road use today, and are giving thorough satisfaction under all normal conditions.

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The RICHARDSON *Improved* BATTERY CASE

The Dole Valve Co., 1923 Carroll Ave. Chicago

NASH



IT REFLECTS distinctly—the good judgment and discrimination of The Nash Motors Company that it has adopted The Dole “Red Dagger” Thermostat as standard equipment on Nash Advanced Six and Special Six cars.

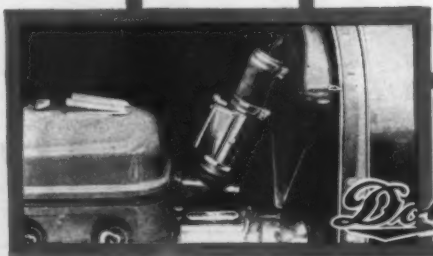
It is extremely complimentary to us.

But *you* are the real beneficiary. You have the phenomenal Nash value and fine performance definitely increased. You now have the thoroughly scientific, much-lauded “Thermostatic Control” and all its consequent satisfaction, yet you pay no more for your favorite car.

An advantage to you.

A tribute to Nash initiative.

A distinct accomplishment for The Dole “Red Dagger” Thermostat.



Automatically Controls Engine Heat Increases Mileage —
Eliminates Need for All Radiator Coverings

Dole **“RED DAGGER”** Thermostat

**PRICE
\$10.00**

The centralized
lubricating system
that guarantees
the right amount
of oil at every
point of the chassis

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Measured lubrication regardless of how tight or loose the bearings may be.

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The Hill "Utility" measuring valves force a predetermined quantity of heavy oil into each bearing.

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CENTRALIZED
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Please send me your book "Once a Day" describing the Hill Utility Chassis Lubricating System.

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Title



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Westinghouse Air Brakes make possible the safe use of the peak speed attainable with the White 100 H.P. motor.

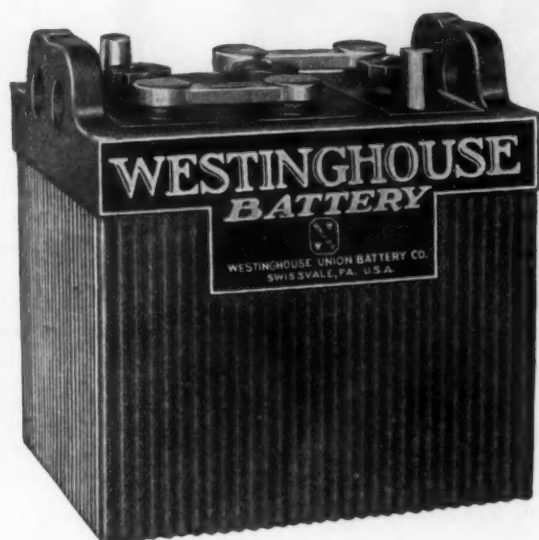
Sudden deceleration, or a complete, smooth, effortless, short range stop, is, with Westinghouse equipment, a reality.

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Automotive Division, Wilmerding, Pa.

WESTINGHOUSE AUTOMOTIVE AIR BRAKES

The Name The Product The Service



A complete line of quality batteries for all passenger cars, trucks and buses.

Westinghouse Batteries are sold and serviced in every latitude from Tasmania to Finland and on every meridian from Colombo to Mexico City and back again.

Westinghouse has capitalized its great purchasing power, engineering ability, research facilities and over fifty years manufacturing experience to build a quality battery that will meet the highest standards.

Users of Westinghouse Batteries are assured of dependable battery service wherever they go because of the 5700 Westinghouse stations that have been established at home and abroad.

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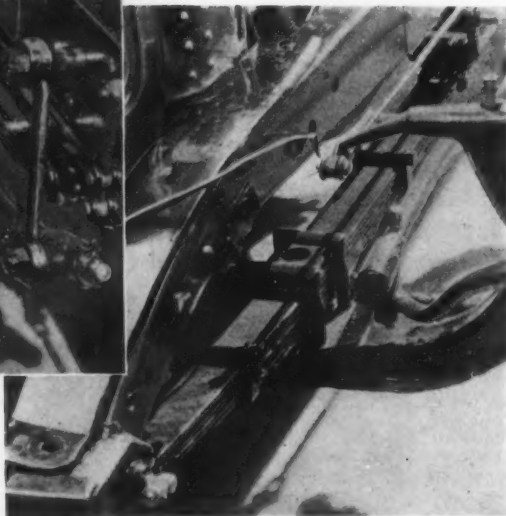
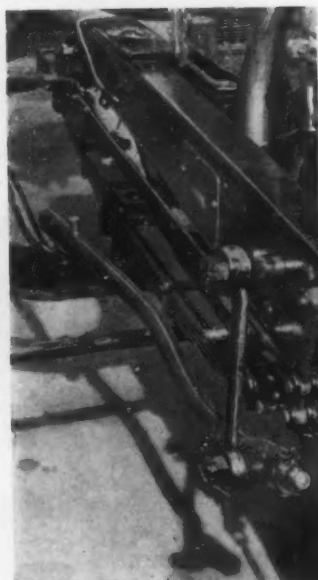
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The Studebaker Big Six Custom Brougham



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Data on Chrome-Vanadium Spring Steel and other Vanadium Automotive Steels—and the counsel of our Metallurgists—are available without obligation.

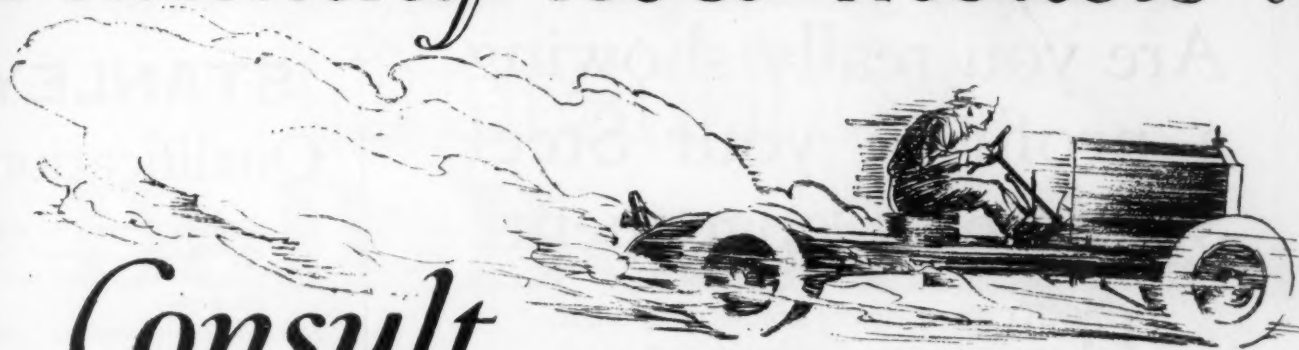
VANADIUM CORPORATION
OF AMERICA
NEW YORK DETROIT

Studebaker front and rear chassis springs are Chrome-Vanadium Steel

VANADIUM STEELS

for strength, toughness and durability

Planning new models?



Consult propeller shaft specialists

AS soon as motor specifications, wheelbase and spring suspension are decided upon, call a Spicer engineer into consultation.

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Correct propeller shaft specifications can be lined up best in cooperation with a specialist.

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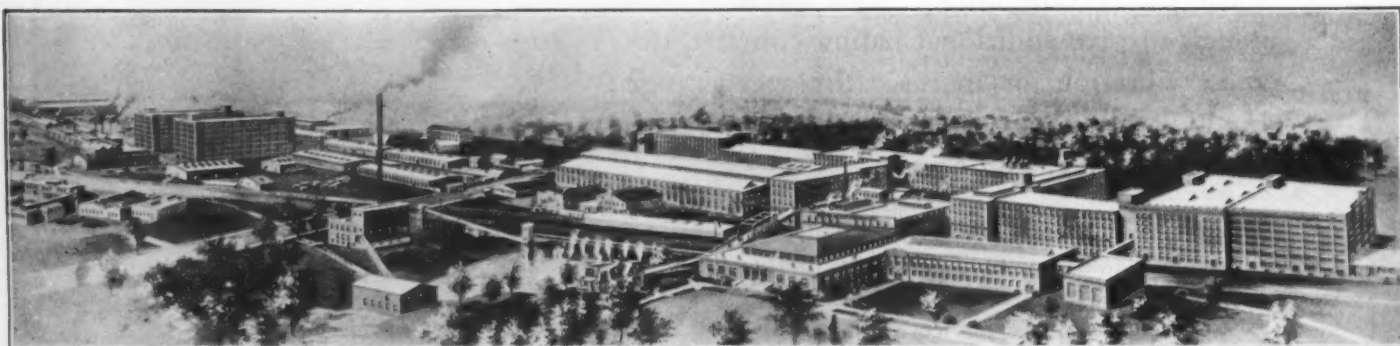
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1. The Stanley Works is the largest manufacturer of steel hardware and carpenters' tools in the world.
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8. We now furnish large quantities of steel stampings to the leading automobile manufacturers.
9. All work done under equitable guarantees.



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STANLEY STEEL STAMPINGS

STANLEY



New Departure Quality Ball Bearings

Adjustability is
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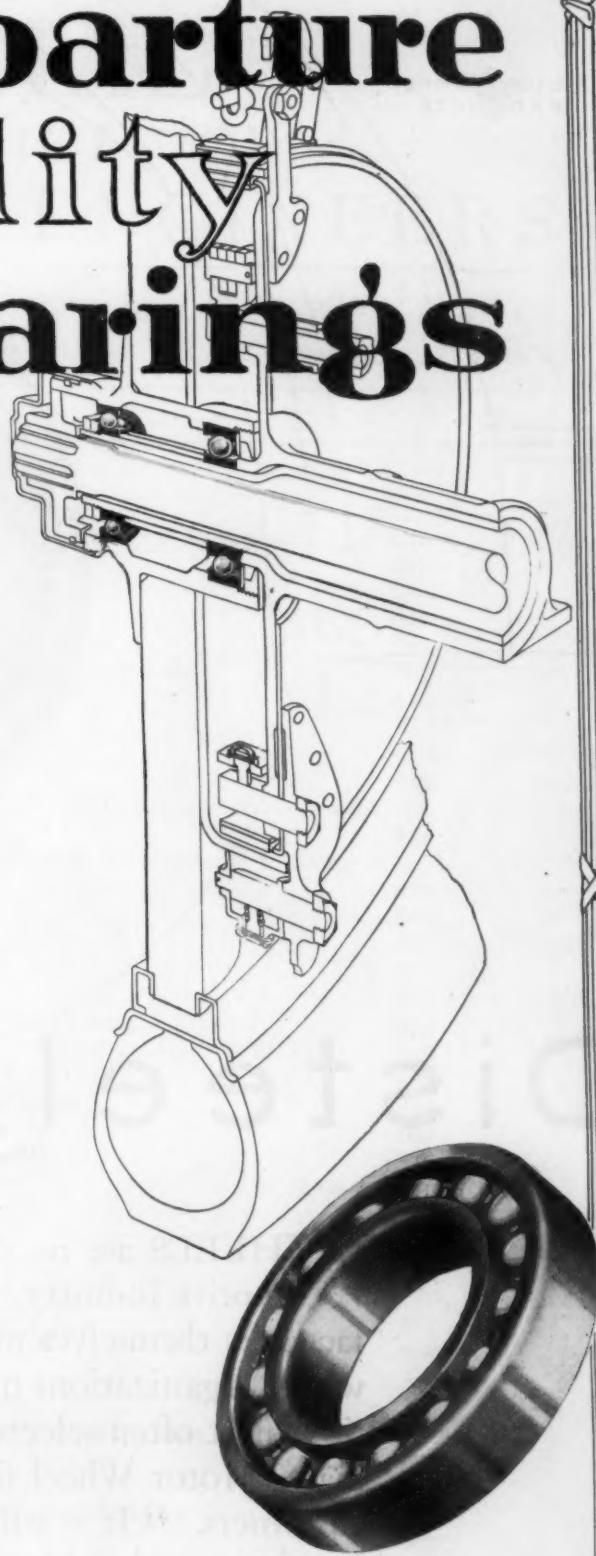
NEW Departure Ball Bearings take rear wheels out of the tinkering and put them into the fool-proof class.

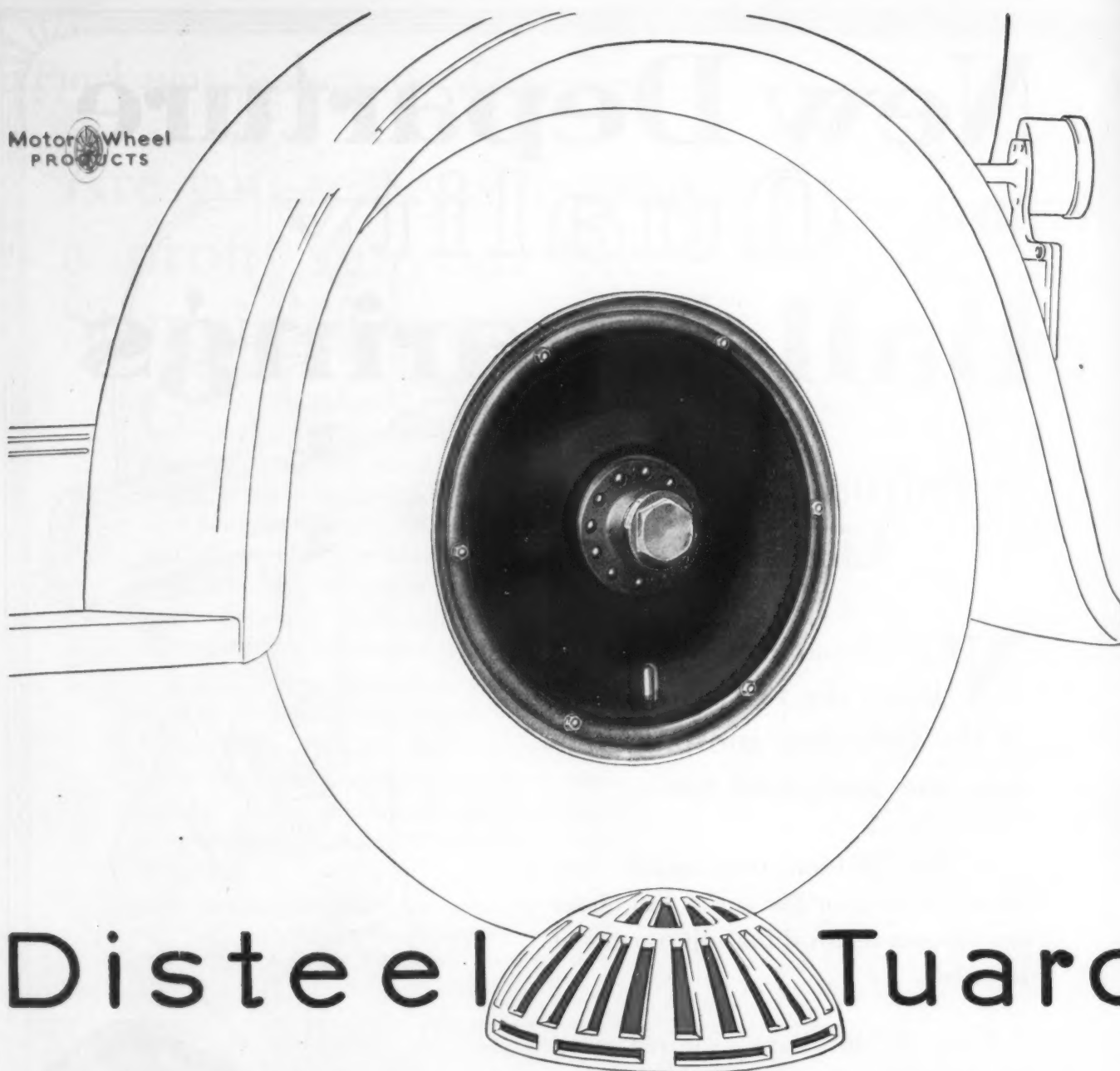
In this position they enable rear wheels to run for the entire life of the car without removal for adjustments of any kind.

Even the lubricant required (and introduced by pressure fittings) is reduced to a minimum.

New Departures outsell because they excel—but the *quality* is even outstripping *quantity*. In the last five years New Departure production has been doubled, while New Departure *endurance* has been increased 600 per cent.

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MOTOR WHEEL CORPORATION, LANSING, MICHIGAN
WOOD WHEELS , STEEL WHEELS , STAMPINGS

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Published by the SOCIETY OF AUTOMOTIVE ENGINEERS, INC., 29 W. 39th St., New York

T. J. LITTLE, JR., President COKER F. CLARKSON, Secretary C. B. WHITTELSEY, Treasurer

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December, 1926

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The purpose of meetings of the Society is largely to provide a forum for the presentation of straight-forward and frank discussion. Discussion of this kind is encouraged. However, owing to the nature of the Society as an organization, it cannot be responsible for statements or opinions advanced in papers or in discussions at its meetings. The Constitution of the Society has long contained a provision to this effect.



*The Basis
of Smooth Engine
Performance ~*

WYMAN-GORDON
The Crankshaft Makers
Worcester, Mass.
Harvey, Ill.

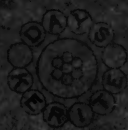




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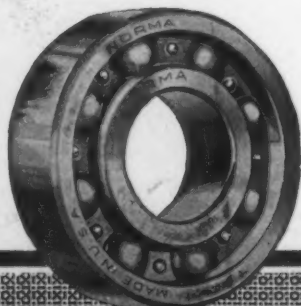
Whether it be used for pleasure or profit, the value of a car—or truck—lies in its capacity for useful service. Many a breakdown is traceable to a failure which would have been avoided by using "Norma" Precision Ball Bearings.

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Personal Notes of the Members

Items regarding changes in business connections, promotions, etc., are desired from the membership for insertion in these columns. This will enable members to keep their friends informed of their whereabouts and will also assist in keeping the records of the Society up to date.

J. O. Almen, who until recently was secretary and chief engineer of the Almen Motors, Inc., Seattle, is now affiliated with the General Motors Corporation Research Laboratories, Detroit.

Michael J. Annick has accepted a position with the Finn Iffland Co., Scranton, Pa. Prior to making this connection he was draftsman and detailer for the Sheldon Axle & Spring Co., Wilkes-Barre, Pa.

Ralph Baggaley, Jr., has been appointed assistant equipment engineer in the Department of Highways, State of Pennsylvania, Harrisburg. He was formerly engine representative for the Lexington Machine Corporation, and Elco Works of the Electric Boat Co., Bayonne, N. J.

C. O. Ball, body engineer for the Yellow Truck & Coach Mfg. Co., has removed from Chicago to the General Motors Truck Co.'s plant at Pontiac, Mich., where the engineering division of the Yellow Truck Company is now located.

C. O. Bech, who for the last ten years has been associated with the Texas Co., New York City, in the capacity of superintendent of motor equipment and transportation, has joined the ranks of the General Motors Truck Co., Pontiac, Mich., as superintendent of transportation. He will continue to make his headquarters in New York City.

Edward H. Belden has been elected president of the Beldens Patents Co., Toledo. Formerly he was vice-president and general manager of the Belden Engineering Co., of that city, which is no longer in business.

Harry E. Blacker is now associated with the Breay Nash Motors, Ltd., Toronto, Ont. He was previously service manager for the Nash-Buffalo Corporation, Buffalo.

Ora G. Blocher has accepted a position as engineer for the General Motors Corporation, Detroit. Until recently he was assistant chief engineer of the Hess Aircraft Co., Wyandotte, Mich.

Arthur Brock, Jr., who was previously owner and general manager of the A. Brock, Jr., Tool & Mfg. Works, Philadelphia, is no longer associated with this organization. No announcement has been made regarding his future plans.

Burton W. Brodt is now affiliated with the Detroit sales office of the Firestone Steel Products Co., Akron, Ohio. He was formerly sales engineer for the American Autoparts Co., Detroit.

Donald B. Brooks has become associated with the Studebaker Corporation, South Bend, Ind., and is located in the experimental engineering laboratory. Previously he was an engineer in the mechanical department of the Texas Co., New York City.

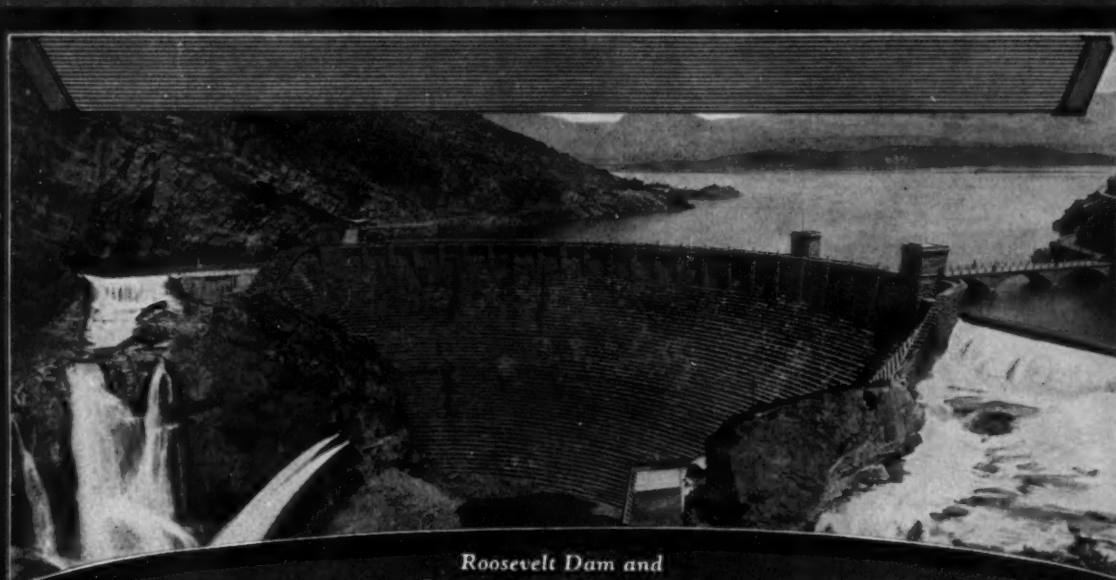
Frederic Canali, who until recently was draftsman and designer in the engineering laboratory of the Ford Motor Co., Dearborn, Mich., is now chassis layout man for the Checker Cab Mfg. Co., Kalamazoo, Mich.

(Continued on p. 22)

See
America
First



Through
Ainsworth
Windshields



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Storage Reservoir, Arizona

Credit Bureau of U. S.
Reclamation

SKILL

The skill of the builder is reflected in the results of his work.

Ainsworth Products are the direct result of unusual skill developed through years of painstaking effort.

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Grolan Gasoline Gauges

*Factory
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*America's Finest
Motor Cars
and Busses*

*"No Instrument Board
Complete Without One"*

Frank A. Groves
PRESIDENT

THE GROLAN MANUFACTURING CO.
DAYTON, OHIO.

PERSONAL NOTES OF THE MEMBERS

Continued

Charles H. Chatfield has been appointed associate professor of aeronautics at the Massachusetts Institute of Technology, Cambridge. He is also affiliated in a consulting capacity with the Pratt & Whitney Aircraft Co., Hartford, Conn. Prior to establishing this connection Mr. Chatfield was chief airplane engineer for the Wright Aeronautical Corporation, Paterson, N. J.

C. H. Dengler, who formerly was associated with the International Harvester Co., in the engineering department of its motorcoach plant at Springfield, Ohio, has accepted a position as designer and engineer for the New Way Motor Co., Lansing, Mich. He assumed his new duties on Dec. 1.

G. E. Denis has severed his connection with the Delling Motors Co., Collingswood, N. J., where he was in charge of manufacturing. His plans for the future have not been announced.

Charles W. Doane has been elected president of the C. W. Doane Radio Corporation, Detroit. He was previously sales representative for micarta and automotive ammeter products for the Westinghouse Electric & Mfg. Co., also of Detroit.

Nicholas Dreystadt, until recently general superintendent of the Cadillac Motor Car Co., with headquarters in Chicago, has been appointed general service manager and transferred to Detroit.

George E. Edmunds has been made chairman of the board of directors of the Edmunds & Jones Corporation division of the C. M. Hall Lamp Co., Detroit, having formerly been president of this organization.

Beldon G. Elliott has accepted a position as motor-truck salesman in Watertown, N. Y., for the International Harvester Co. of America, Ogdensburg, N. Y. Prior to establishing this connection he was associated with the Mack-International Motor Truck Corporation, Allentown, Pa., in a similar capacity.

Guy M. Ferguson has severed his connection with the Rolls-Royce of America, Springfield, Mass., where he was engineering assistant. No announcement has been made regarding his future plans.

H. L. Ferris has been appointed assistant director of the maintenance and service division of the Eastern district of the General Motors Truck Co., New York City. Prior to establishing this connection he was service manager of the Autocar Sales & Service Co., also located in New York City.

N. A. Finch, Jr., who until recently was transportation engineer in the engineering service department of the General Motors Corporation, New York City, is now affiliated with the Yellow Truck & Coach Mfg. Co., Chicago.

Ray A. Graham, formerly treasurer of Graham Bros., Detroit, has severed his connection with that organization. His plans for the future have not been announced.

David Gregg is now associated with the A. C. Spark Plug Co., Flint, Mich., and has charge of supercharger development. He was formerly engaged in business for himself as research and consulting engineer on superchargers at Dayton, Ohio.

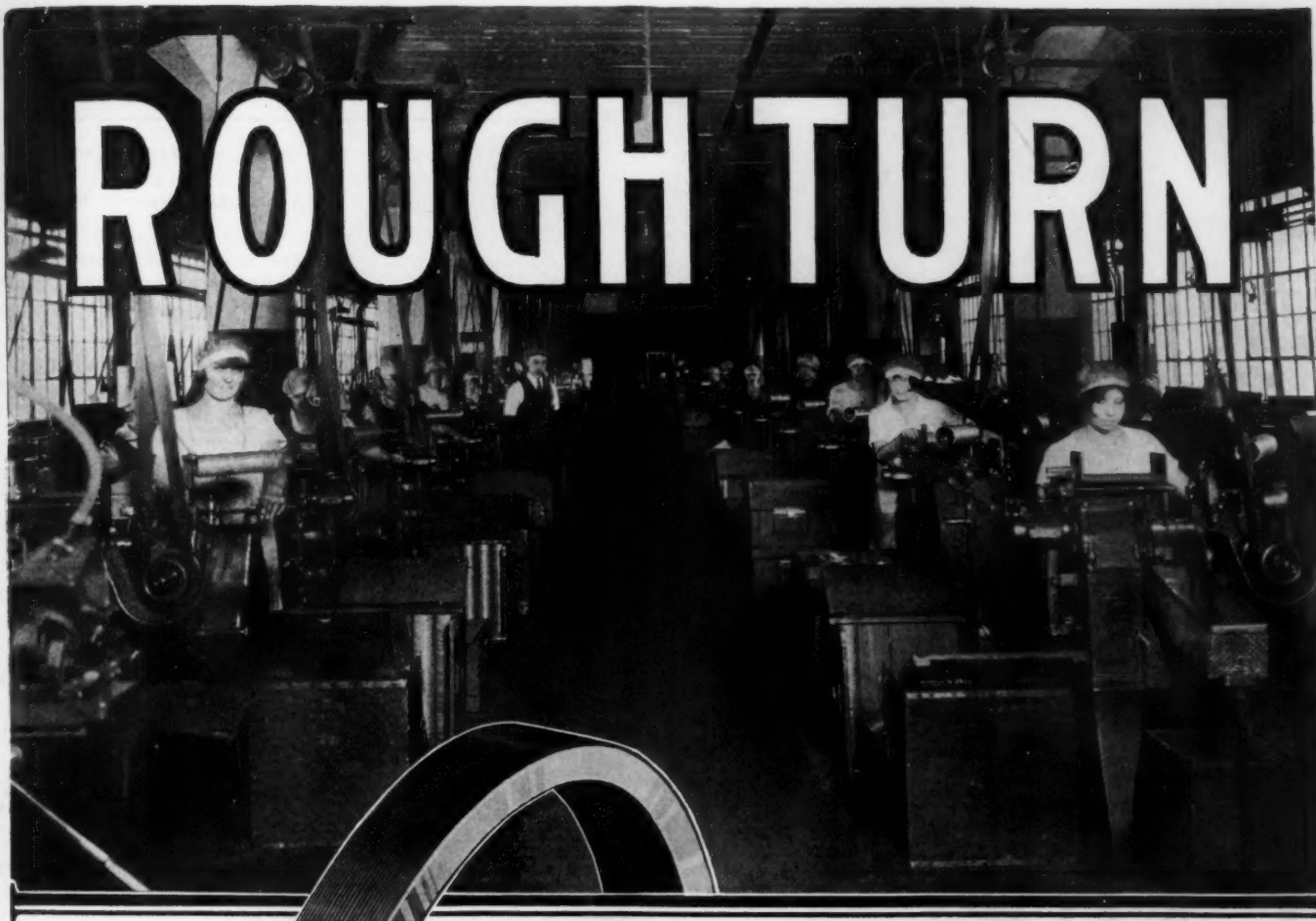
George H. Grundy has been appointed president of the Poldi Steel Corporation of America, New York City. Previously he was general sales manager of Peter A. Frasse & Co., Inc., Hartford, Conn.

Edward H. Gunster, who was until recently chief draftsman for the Sheldon Axle & Spring Co., Wilkes-Barre, Pa., has been elected president and manager of the Auto Spring Service Corporation, Kingston, Pa.

W. S. Haines has accepted a position with the duPont Motors, Inc., Moores, Pa. He was formerly service superintendent of the Newark Flint Co., Newark, N. J.

(Continued on p. 24)

ROUGH TURN



QUALITY Piston Rings

In this department rings are given the first rough turning operation on the periphery, each ring being turned individually by our own process on patented machines. This is done before joint is cut, to guarantee absolute concentricity and yet retain the skin of the casting. Two vital features — concentricity and lasting resiliency.

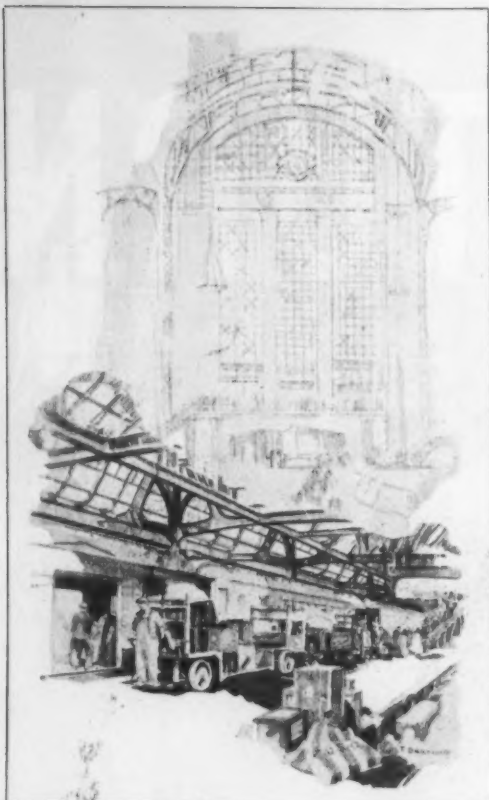
An investigation among manufacturers who specify Quality Piston Rings for original equipment and a thorough analysis of comparative, rigid tests employed before their adoption, will disclose most convincing proof and the real reason for Quality Leadership.

Quality

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The Piston
RING COMPANY
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BATTERIES

Throughout the ages the moving of heavy loads has depended on the brawn of toiling men. Now, fortunately for humanity and thanks to the storage battery, those days are over. Labor saving industrial trucks and tractors, propelled by powerful Exide Ironclad Batteries, are daily lightening man's burdens in industrial plants, mines and railway terminals.

But it is in the cranking and lighting of its automobiles that the general public best appreciates the labor saving abilities of Exide Batteries. Standard equipment on the first automobile to carry electric lights and starter, these batteries ever since, have been the choice of automotive engineers who demand high cranking ability, long life and dependability.

THE ELECTRIC STORAGE BATTERY CO.
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PERSONAL NOTES OF THE MEMBERS

Continued

Mason D. Hanes, who was layout draftsman in the Servel division of the Hercules Corporation, Evansville, Ind., now holds a similar position with the Duesenberg Motors Co., Indianapolis.

A. R. Hopkins has joined the engineering department of the Chandler-Cleveland Motors Corporation, Cleveland. Until recently he was chief engineer of the E. J. Thompson Co., Pittsburgh.

Herbert J. Howarth, who was formerly manager of the research department of *Automotive Industries*, Philadelphia, has been appointed Eastern service representative of the Oakland Motor Car Co., Pontiac, Mich.

E. G. Hulse is now affiliated with the Swinehart Tire & Rubber Co., Akron, Ohio. Prior to establishing this connection he was mold and car equipment engineer for the Kelly-Springfield Tire Co., Springfield, Mass.

Thomas Jackson, who was until recently draftsman for the Ford Motor Co., Dearborn, Mich., has become checker in the engine department of the Continental Motors Corporation, Detroit.

Herbert Jayes has accepted a position with the J. C. McFarland Co., Inc., New York City. He was previously designer of machinery for the Crescent Washing Machine Co., New Rochelle, N. Y.

C. E. Jeffers, who was formerly a consulting engineer with offices at Indianapolis, has been made chief engineer of the Martin-Parry Corporation, York, Pa.

William M. Kaufmann is now mechanical engineer for the Superior Gas Engine Co., Springfield, Ohio. Prior to accepting this position he was engaged in a similar capacity at the tractor works of the International Harvester Co., Chicago.

William H. Kelley has accepted a position as service manager for the Island Motors, Inc., Stapleton, N. Y. He was previously affiliated with the Jandorf Automobile Co., New York City.

Walter C. Keys, who has been associated with the Gabriel Snubber Mfg. Co., Detroit, for 4½ years as manager, has severed his connection with that organization. He plans to continue his engineering work in automobile riding-comfort in which he has specialized for the last 14 years, making his headquarters in Detroit.

V. B. King is now engaged in engineering work for the Bickle Fire Engines, Ltd., Woodstock, Ont., Canada. Formerly he was affiliated with the White Motor Co., Cleveland, as technical apprentice.

Frederick Klein has severed his connection with the Watson-Stillman Co., Aldene, N. J., where he was designing and experimental engineer. No announcement has been made regarding his future plans.

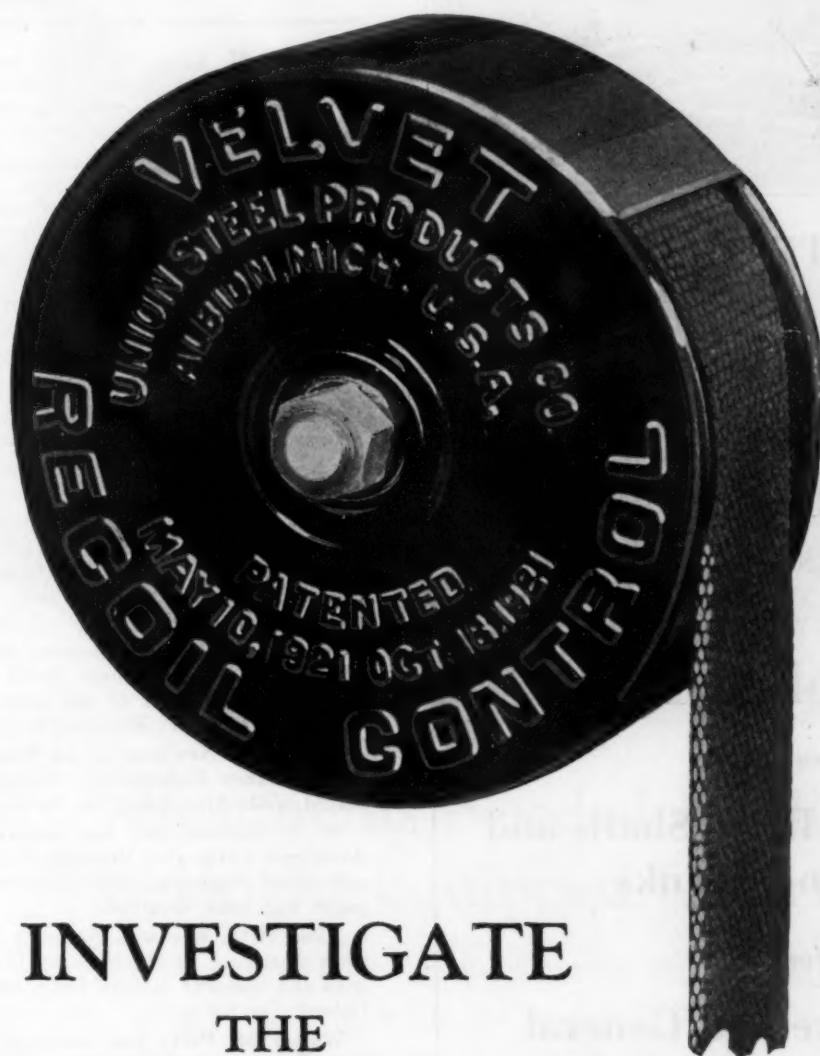
Merle S. Klinch, who formerly attended Ohio State University, Columbus, Ohio, has become engineer in the automatic sprinkler department of the New York Fire Insurance Exchange, New York City.

Axel W. Kogstrom, until recently installation engineer for the John Warren Watson Co., Philadelphia, has become affiliated with the Landis Engineering & Mfg. Co., Waynesboro, Pa.

Robert F. Kohr is now associated with the Studebaker Corporation, South Bend, Ind. He was previously aeronautical engineer of the Bureau of Aeronautics, Navy Department, City of Washington.

Harold F. Lehman, who was until recently sales engineer for the Wheeler-Schebler Carburetor Co., Indianapolis, is now experimental engineer for the Auburn Automobile Co., Auburn, Ind.

(Continued on p. 26)



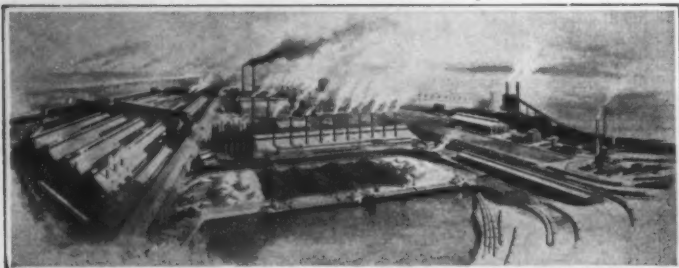
INVESTIGATE THE VELVET RECOIL CONTROL

If the motor car owner never had to concern himself as to why his car rode so well, and if it continued to ride that way during its usefulness to him—he would be satisfied and so would the car manufacturer.

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ALLOY and CARBON STEELS

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Philadelphia: Morris Bldg.	San Francisco: Call Bldg.
Detroit: General Motors Bldg.	Milwaukee: First National Bank Bldg.

PERSONAL NOTES OF THE MEMBERS

Continued

Walter M. Lipps has been made assistant chief engineer in the automotive division of the American Cable Co., Bridgeport, Conn. Prior to accepting this position he was designing engineer for the Maccar Truck Co., Scranton, Pa.

Thomas J. Little, Jr., engineering production consultant, Detroit, and vice-president in charge of engineering for Copeland Products, Inc., of that city, has been appointed chief engineer of the Marmon Motor Car Co., Indianapolis, succeeding D. G. Roos, who has resigned. Mr. Little assumes his new duties on Dec. 1.

H. W. McQuaid, who was formerly vice-president and treasurer of the Precision Gear Blank Co., Canton, Ohio, has become associated with the Timken-Detroit Axle Co., Detroit.

William P. MacCracken, Jr., has joined the staff of the Department of Commerce, City of Washington, having been a member of the firm, Montgomery, Hart & Smith, Chicago.

Chester Malinowski is now associated with the Link-Belt Meese & Gotfried Co., San Francisco.

A. F. Marshall, who was previously experimental engineer for the Yellow Sleeve Valve Engine Works, Inc., East Moline, Ill., has been transferred to the Yellow Truck & Coach Mfg. Co., Pontiac, Mich., and is engaged as experimental engineer in charge of dynamometer and road tests.

A. P. Munning has become affiliated with the American Trading Co., Kobe, Japan. Prior to establishing this connection he was director of the department of research and development of A. P. Munning & Co., Matawan, N. J.

Arthur B. Newman is no longer automotive engineer in the Ordnance Department, City of Washington, but is associated with Alex Laughlin & Co., Pittsburgh, as draftsman.

W. T. Norton, Jr., has severed his connection with the American Cable Co., Bridgeport, Conn., where he was assistant chief engineer. No information regarding his future plans has been received.

Allen Orth, who was formerly a student at the Massachusetts Institute of Technology, Cambridge, is now affiliated with the General Motors Corporation Research Laboratories, Detroit.

Walter M. Petty has accepted a position with the Buda Co., Harvey, Ill. Prior to establishing this connection he was chief engineer and production manager for the Maccar Truck Co., Scranton, Pa.

An office for the practice of consulting engineering has been opened in New York City by P. J. Piccirilli. He was previously chief engineer of the Alcolac division of the U. S. Industrial Alcohol Co., also of New York City.

F. R. Pleasonton, who until recently was chief engineer of the Murray Body Corporation, Detroit, is now associated with the Edward G. Budd Mfg. Co., Philadelphia.

Clarence H. Powell has resigned as professor in charge of aeronautics at the University of Detroit, Detroit. His plans for the future have not been made known.

Chester S. Ricker, consulting engineer at Indianapolis, has become associated with the Waukesha Motor Co., Waukesha, Wis.

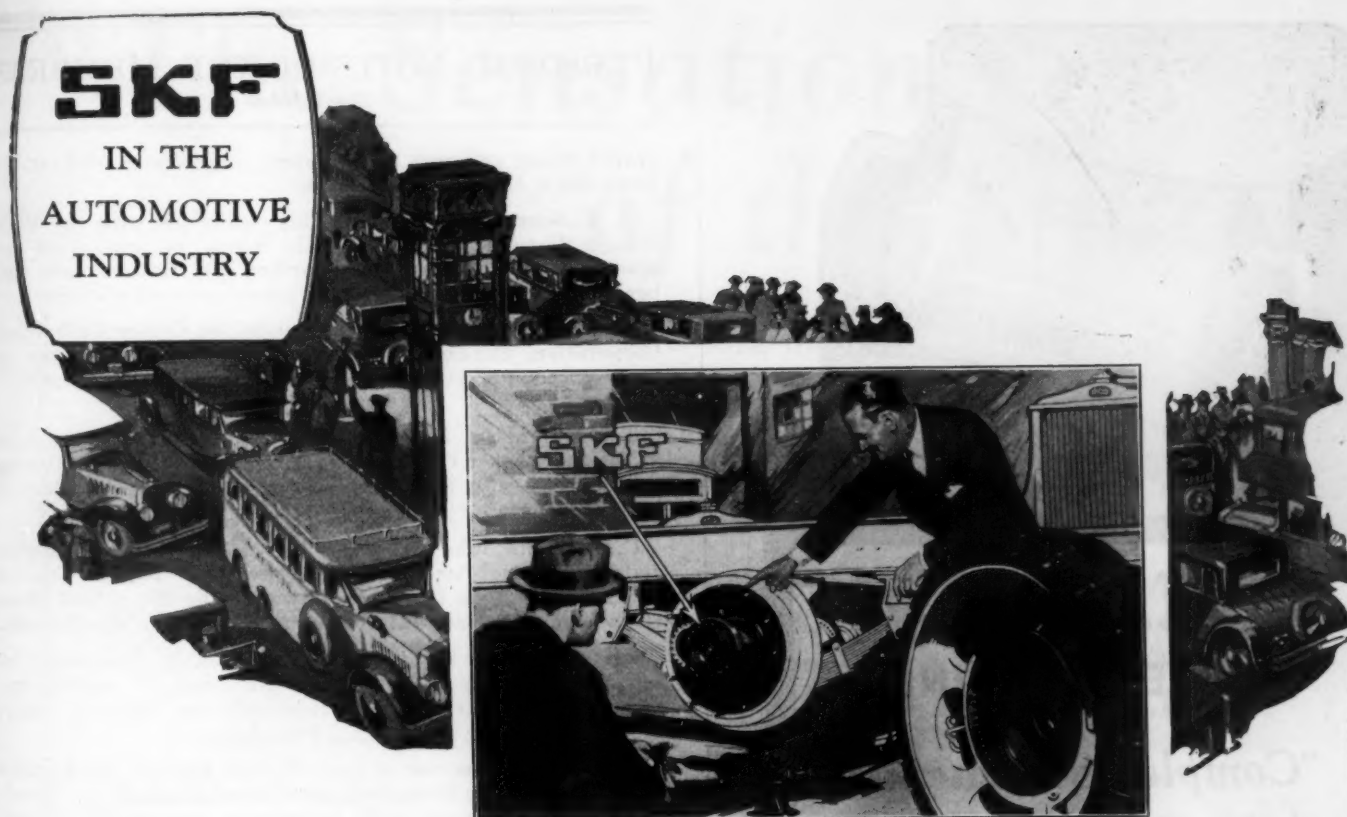
Walter C. Robbins has accepted a position with the Houde Engineering Corporation, Buffalo. His previous business connection was with the New Departure Mfg. Co., Bristol, Conn., where he was a checker.

A. W. Scarratt, who until recently was mechanical engineer for the Minneapolis Steel & Machinery Co., Minneapolis, is now assistant chief engineer of the Hyatt Roller Bearing Co., Newark, N. J.

Earl V. Schaal has been elected president and manager of the Sanitary Retinning & Galvanizing Corporation, Buffalo. Previously he was metallurgical engineer for the Elliott-Fisher Co., Harrisburg, Pa.

J. R. Schermerhorn is engaged in manufacturing analysis for the Western Electric Co., Chicago. He was formerly re-

(Concluded on p. 28)



No Adjustments Needed on these Hess-Bright Equipped Gear Drives

For years—one of the leading motor truck manufacturers has been using Hess-Bright Deep-Groove Ball Bearings, marked **SKF**, on the rear axles in the gear reduction drives.

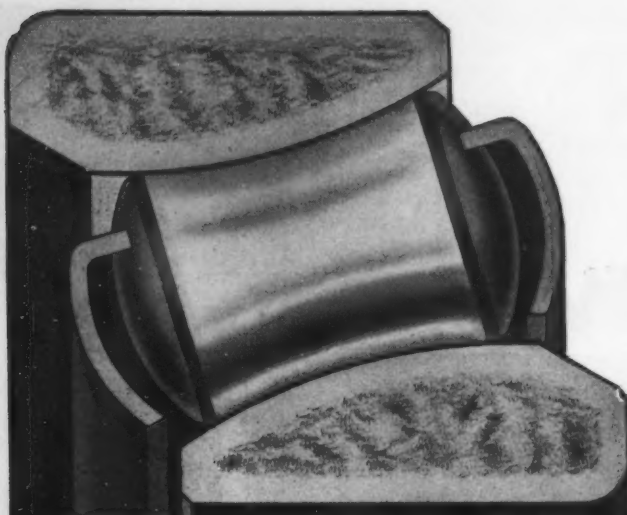
These bearings are an important contributing factor toward reliable operation. They show hardly a trace of service after miles of going, maintain gear tolerances and—require no adjustments to compensate for wear!

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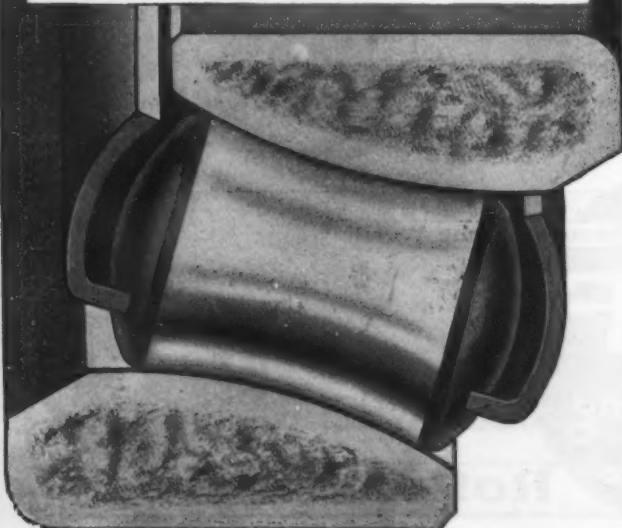
"Self-Aligning"
ROLLER BEARING
PAT. & PATS. PENDING

"Complete Satisfaction"

"It is natural that I should express my appreciation for the extraordinary good service that the Shafer Bearings have given us. We have about 2,000 cars in this territory equipped with Shafer Bearings and giving complete satisfaction."

MR. E. B. WHITE, Service Mgr.
Nikart Mtr. Sales Co.
South Bend, Ind.

SHAHER BEARING CORPORATION
6501 West Grand Avenue
CHICAGO, ILL.



PERSONAL NOTES OF THE MEMBERS

Concluded

search fellow and part time student on graduate work at the Iowa State College, Ames, Iowa.

A. F. Schroeder has severed his connection with the Velie Motors Corporation, Moline, Ill., where he was chief inspector. No information regarding his future plans has been received.

P. G. Sedley is now associated with the Carter Carburetor Corporation, St. Louis. Until recently he was manager of the car equipment division of the Lincoln Products Co., Chicago.

T. S. Sligh, Jr., has been appointed engineering physicist at the Studebaker Corporation, Detroit. Prior to establishing this connection he held a position as physicist at the Bureau of Standards, City of Washington.

C. F. Smith, who was previously engineer in the engine division of the American LaFrance Fire Engine Co., at Elmira, N. Y., has been transferred to the Bloomfield plant of the company and will be on the factory manager's staff.

Eastman Smith has joined the advertising department of Johns-Manville, Inc., New York City, and is engineering editor of its monthly publication. He was formerly engineering writer for Lefax, Inc., Philadelphia.

Stanwood W. Sparrow is now affiliated with the Studebaker Corporation, South Bend, Ind., as mechanical engineer. Previously he was engineer in the automotive powerplants section of the Bureau of Standards, City of Washington.

C. R. Spooner has become associated with the White Motor Co., Cleveland, having formerly been connected with the Commerce Motor Truck Co., Ypsilanti, Mich.

H. E. Stearns, Jr., who until recently was field technical adviser for the General Motors Export Co., Sydney, New South Wales, has been appointed service manager for the General Motors (Australia) Proprietary, Ltd., Adelaide, South Australia.

Ralph H. Tyler has accepted a position with the Federal Drop Forge Co., Lansing, Mich. He was previously general superintendent of the Ladish Drop Forge Co., Cudahy, Wis.

O. W. Warner has resigned as research engineer in the motorcoach department of the International Harvester Co., Springfield, Ohio. His plans for the future have not been made known.

William B. Wheatley is engaged in testing aircraft engines for the Pratt & Whitney Aircraft Co., Hartford, Conn. Formerly he was flying instructor, pilot and assistant to the chief engineer of the Aerial Service Corporation, Hammondsport, N. Y.

P. A. Wickes, who was until recently chief engineer for the Willamette Iron & Steel Works, Portland, Ore., has been appointed logging engineer for the Loggers & Contractors Machinery Co., also of Portland.

George L. Willman is now merchandising counsel for the Dartwell Corporation, Chicago. Previously he was account executive on Studebaker Corporation advertising with Lord & Thomas, Chicago.

James Wills has become machine designer for the Combustion Engineering Corporation, New York City. He formerly held a similar position with the Powers Accounting Machine Corporation, New Brunswick, N. J.

Harold G. Wilson is now affiliated with the Timken Roller Bearing Co., Chicago, as engineer in the tractor and implement bearings division.

Raymond N. Wing, who was until recently aeronautical engineer for the Consolidated Aircraft Corporation, Buffalo, has become structural engineer for the Beaver Products Co., also of Buffalo.

"The Sensation of the Show!"

The following German
built cars and buses
equipped with the

BOWEN SYSTEM

of Chassis Lubrication
were exhibited at the
Berlin Automobile Show

Adler

Audi

Brennabor-Omnibusse

Büssing

Daag

AEG-Elektrokarren

Faun-Omnibus

Hansa-Lloyd-

Trumpf-Ass

Hansa-Lloyd

Omnibus

MAN

NAG

Pilot

Pluto

Presto

Steyr

van der Zypen Charlier

That is what the Berlin newspapers termed the Bowen
System of Chassis Lubrication when describing the 1926
German Automobile Show

FOR years European car builders have been endeavoring to work out a satisfactory method of centrally controlled lubrication for the chassis but it was not until the introduction of the Bowen System that they found one which met their requirements and one which they felt justified in building into their machines.

That the Bowen System has the approval of the German automotive industry is clearly shown by the fact that fifteen of the leaders exhibiting at the Berlin Show had their cars equipped with it.

The Bowen System is not an accessory but a standard equipment part that must be installed before the car leaves the factory.

Bowen Products Corporation
Auburn, New York

BOWEN SYSTEM

OF CHASSIS LUBRICATION

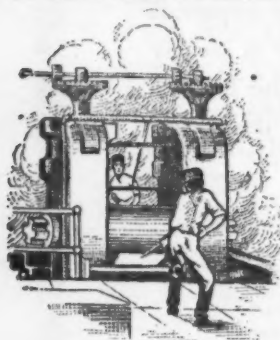


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Steel Sheets that are particularly suited to their specialized lines. We supply Automobile Sheets in all grades—also deep drawing qualities, for special work. THURITE gives exceptional results in the dies. This Company will be pleased to extend

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Automobile Sheets—all grades
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Special Sheets for Stamping
Long Terne Sheets
Tin and Terne Plates. Black Plate, Etc.

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Chicago Cincinnati Denver Detroit New Orleans New York
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Pacific Coast Representatives: UNITED STATES STEEL PRODUCTS CO., San Francisco
Los Angeles Portland Seattle

Export Representatives: UNITED STATES STEEL PRODUCTS CO., New York City

Our Sheet and Tin Mill Products represent the highest standards of quality and utility. In addition to Automobile Sheets, we manufacture Black and Galvanized Sheets, Formed Roofing and Siding Products, Electrical Sheets, Special Sheets, Tin and Terne Plates, etc., for all purposes. Address nearest District Sales Office.

Notes and Reviews

This column, which is prepared by the Research Department, gives brief items regarding technical books and articles on automotive subjects. As a general rule, no attempt is made to give an exhaustive review, the purpose being to indicate what of special interest to the automotive industry has been published.

Die Wirtschaftlichkeit von Elektro-Omnibus-Betrieben. By P. Friedmann. Published in *Der Motorwagen*, Sept. 20, 1926, p. 613.

Another contribution to the common urge in Germany for the use of domestic fuel, this article presents in favorable light the electric as compared with the gasoline motorcoach. Its easier riding qualities, due to freedom from gear-shifting and from the vibration associated with the gasoline-engine, are beneficial for passenger, highway and vehicle, and are advantages assumed. Superiority in these respects entitles the electric motorcoach to serious consideration; the claim that should finally convert the operator to its use is economy.

To make good this last and most vital claim the author compares the cost of operating, with gasoline and electric vehicles, a motorcoach line about 6 miles from terminus to terminus, with stops on an average every 1600 ft. and on which the vehicles operate on a 10-min. headway and at an average speed of 14 m.p.h. The capital investment for the electric vehicles is shown to be about 25 per cent greater than for gasoline-driven motorcoaches, due to the cost of the batteries and the equipment necessary for their maintenance. In indirect charges the same ratio holds true, and here the electric vehicle is represented by the lower figure, since depreciation is figured for it at 12 as against 20 per cent for the gasoline motorcoach and the cost of battery renewal is omitted to be included later as fuel cost under direct charges. Wages to employees and direct costs of operation, for fuel or power, lubricants, repairs and tires, are both somewhat higher in the case of the electrically operated line. This advantage is offset by the saving in indirect charges, and when the three items are totalled the operating cost of the electric vehicle is shown to be about 3 per cent less than that of the gasoline-driven motorcoach.

Comment Concevoir la Voiture de Serie? By S. Damien. Published in *Omnia*, October, 1926, p. 403.

The present article has an appropriate setting in this number of *Omnia*, which is devoted to the French automotive industry as epitomized in the Paris Salon. It contains detailed advice on design to the manufacturer planning on large-scale production for the French market.

A line of two models is recommended, a four-cylinder car for purely business purposes, and a six-cylinder combination business and pleasure vehicle. For American automobiles the value of the coefficient k is said to lie between 0.100 and 0.115 as derived from the formula

$$k = 12.15 cr/dp$$

where

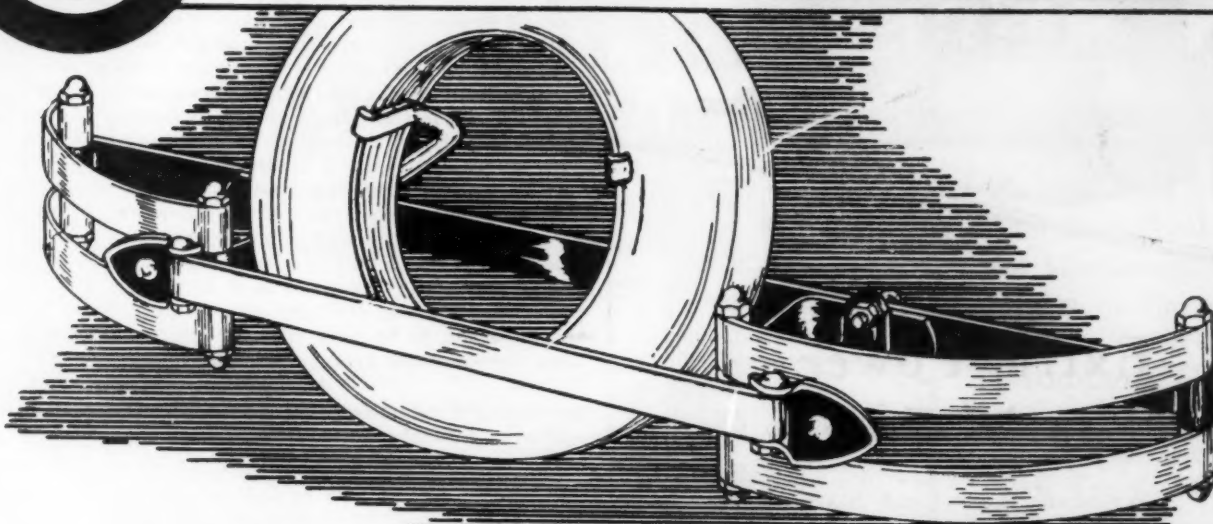
c = cylinder capacity in cubic inches
 d = the diameter of the wheels in inches
 p = the total weight in pounds
 r = the gear-reduction ratio

To meet conditions in France, where flexibility must be sacrificed to fuel economy, this coefficient must be reduced to between 0.07 and 0.09. For the four-cylinder car the following specifications are suggested: weight, 1150 kg. (2535.29 lb.); cylinder capacity, 1200 cc. (73.23 cu. in.); and tires, 715 x 115 mm. (28.15 x 4.53 in.); and for the six-cylinder; weight, 1300 kg. (2865.99 lb.); cylinder capacity, 1800 cc. (83.68 cu. in.); and tires, 730 x 130 mm. (28.74 x 5.12 in.).

Among other design features included in the suggested program are Ricardo-type combustion-chamber; single-plate dry-disc clutch; three-speed gearbox; and a banjo-type rear axle. Special means taken to secure silence of operation are outlined, and the necessity of carrying standardization of parts as far as possible is emphasized.

(Continued on p. 32)

C TIRE-GARD



Protect Your Spare Tire, Too!

Tire Carrier protection as well as efficient fender protection is provided by this smart combination of the Tire-Gard with your C G Paragard.

Easily swung open for spare tire removal, the Tire-Gard features convenience as well as rugged dependability.

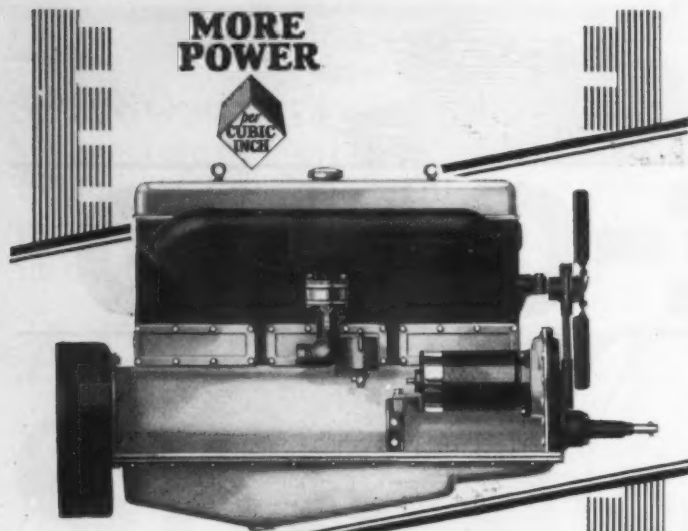
Furnished single or double, this latest mem-

ber of our collision-absorbing family is, indeed, a fitting companion to the Paragard—which so ably serves the tens of thousands of motorists who demand unfailing fender protection.

Be among the first to possess and appreciate Tire-Gard advantages. Realize now on the improvement in appearance and the added protection assured.

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C *oil tempered* **BUMPERS**



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Extra Power That's Free!

Wisconsin Fours and Sixes deliver a surplus of power that you don't pay for. It is a "dividend" on the overhead valve design upon which Wisconsin has long specialized.

For trucks, busses, tractors or industrial machinery, these great motors reach the peak of economy. Precision shop practice has brought longer service life. Maintenance cost is far below the ordinary. "More Power per Cubic Inch" means the lowest-cost POWER you can buy. Let us send you the figures and proof.

Wisconsin Motors are made in a full range of Sixes and Fours, from 20 to 120 H.P., for trucks, busses, tractors and construction machinery, including models housed as industrial units.

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Wisconsin
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NOTES AND REVIEWS

Continued

Driving, Steering and Braking on All Four Wheels. Published in *The Commercial Motor*, Oct. 12, 1926, p. 222.

The unconventional design of this truck was intended to give it the efficiency of a creeper-track machine in traversing roadless country and better spring-suspension than the ordinary vehicle. Additional advantages claimed are the obviation of wheel-spin and the provision of high ground-clearance without undue increase in the height of the platform.

A single differential distributes the drive to all four wheels. A feature of the brake-drums, which permits braking on all four wheels, is that they can act as auxiliary driving-wheels when the vehicle is traveling over any abnormal obstruction. The four-wheel steering system is said to be laid out so that no involuntary steering results at any speed. All four wheels are permitted freedom of movement individually.

According to the claims made, the truck has proved its practicability in extensive tests and is now in commercial production. The chassis is said to present little more complication than the ordinary vehicle and, once its parts are standardized, to be only slightly more expensive to produce than the standard type.

Increasing Production with New Equipment. By Charles O. Herb. Published in *Machinery*, October, 1926, p. 81.

Within the last 2 years the company whose production methods are the subject of this article is said to have spent several million dollars for new machines and equipment. Not only are these aids to manufacture described in detail but their methods of operation are dealt with to some extent and the percentage of increase in production that they make possible is noted. The figures on speed of manufacture were derived from time-study cards and show increases in production per man of 200, 300, 400 and in one instance as high as 1257 per cent.

Among the operations covered are turning crankshaft bearings and pins, buffing and polishing operations, clutch case manufacture, turning camshafts, finishing differential cases, milling the keyway in axle shafts, tapping nuts, burnishing spiral-bevel pinions, drilling holes in clutch fly-wheels, grinding holes in valve lifter rolls, grinding the pin-hole in valve-lifters, drilling and reaming bolt holes in clutch covers, diamond-boring the crank end of connecting-rods, machining the bell housing end of crankcases, milling crankcases and drilling 34 holes in them, and threading studs.

The Works of Minerva Motors. Published in *The Automobile Engineer*, October, 1926, p. 363.

In the recent reorganization of its works, Minerva Motors adopted modern ideas of factory layout customarily associated with large-quantity production, although its output is only 10 cars per day divided among three models.

In this article a brief historical summary first cites the successive steps by which the Minerva Motors has enlarged its facilities until now the various plants cover 20 acres and contain 2000 machine-tools driven by 500 motors representing an aggregate nominal horsepower of more than 4000. The detailed descriptive matter is confined to the parent factory at Antwerp where the chassis are machined and erected. A planning department carefully studies every detail of a new chassis from the viewpoint of manufacturing possibilities to assure economic and convenient production routine. Rigorous inspection is carried out for raw materials and for parts during and upon completion of manufacture; every piece except the smallest standardized items are examined.

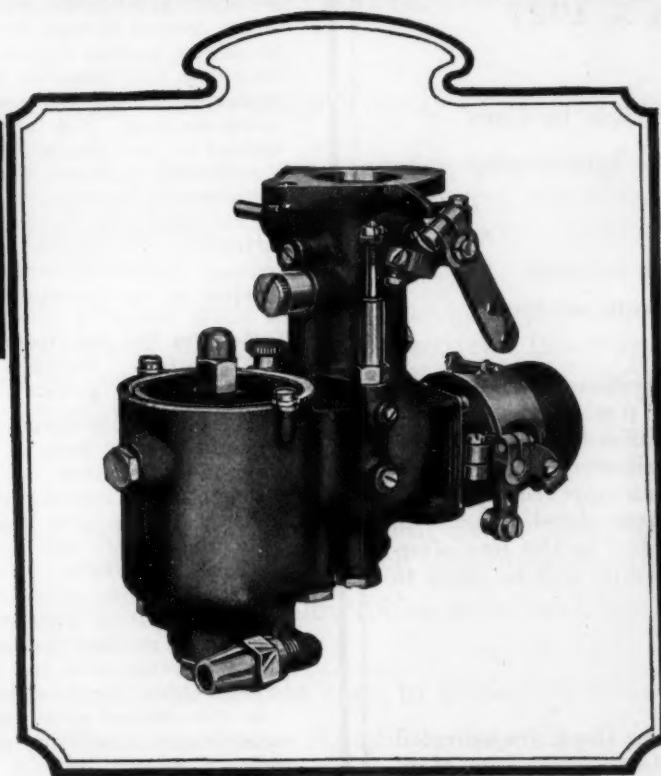
Machine-tools are now arranged according to sequence of operation instead of according to type as previous to the reorganization. In spite of its small production, Minerva has been able to use special-purpose equipment by making such machines adaptable to all three models built and in the

(Continued on p. 34)

STROMBERG

SPECIAL CARBURETORS

Engineered and Tested Individually for Mechanical Precision of Performance. There's a Stromberg Carburetor for Every Make and Model of Car, Truck, Boat or Aeroplane.



FOR—Action
—Precision
—Dependability
—Power and
—Durability



With Two Speeds and Adjustable pressure there is none like the Stromberg Electric Windshield Wiper. "Built like a Stromberg Carburetor."

A trifle more expensive in the beginning, Stromberg Carburetors are cheapest in the long run. THERE'S A REASON—Absolute Reliability under the most rigid tests known to the Automotive Industry—STROMBERG ALWAYS WINS!

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27th Annual National AUTO SHOWS

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GRAND CENTRAL PALACE
Jan. 8-15, 1927

CHICAGO
COLISEUM
Jan. 29-Feb. 5, 1927

The Latest and Best in Cars
The Newest in Accessories

with two new features—

A light truck section
A shop equipment section

The Shop Equipment Sections will be open to the trade only until 3 p.m.—except on the opening day. This will afford factory service managers, wholesale distributors, dealers and service station operators an opportunity to inspect in comfort the latest developments in service machinery and tools. In the late afternoon and evening the exhibits will be open to the public.

TRADE DAYS

At the shows the Trade Days, inaugurated two years ago, will be in force again. On Monday and Tuesday at both shows, the trade will be admitted until 1 p.m.

Tickets for Trade Days and Shop Equipment sessions will be supplied to all who are entitled to them, in advance and on application at the buildings.

Auspices of National Automobile Chamber of Commerce, Inc., with the cooperation of Motor Accessory Manufacturers Association.

S. A. MILES, Manager
366 Madison Ave.,
New York City

NOTES AND REVIEWS

Continued

case of the more elaborate pieces, by building them on a production basis and selling them to other firms. To illustrate the type of equipment used, some of the more interesting operations on the cylinder-block, crankcase, crankshaft, sleeves, and eccentric shaft are dealt with in detail.

Electric Railways Now Operate Approximately 6400 Buses.
Published in *Aera*, October, 1926, p. 448.

For the third year *Aera* presents in its convention number a summary of motorcoach operation by electric railways in the preceding year. Now 336 companies cover 14,907 miles of route with 6400 motorcoaches; an increase of 85 companies, 2800 miles and about 2000 vehicles since Oct. 1, 1925. The rate of growth in the last 12 months has almost reached that established in 1925.

While more than half of the companies operate in cities or in suburbs, only 2902 miles is included in this type of service. Interurban routes maintained by 62 companies solely devoted to such traffic and 67 interested in both kinds of service account for the remaining mileage. For the first time data are presented on the extent to which standees are permitted; of the 197 companies reporting on this point, 151 carry standees. The increase in double-deck vehicles is commented on, and finally a table is presented listing, by States, the electric railways operating motorcoaches; the date of initiation of service; the miles of route classified as city or suburban and interurban, and as feeder, coordinate or auxiliary; the number and makes of vehicles with their seating capacities; fares; transfer arrangements; and whether or not standees are carried.

Difficulties Met and Overcome in Bus Maintenance. By James W. Cottrell. Published in *Operation and Maintenance*, Oct. 10, 1926, p. 14.

A fleet of approximately 1000 motorcoaches of about 20 different makes kept in 25 garages presents a difficult maintenance problem. As an example of its magnitude, the article cites an instance of 374 spring breakages in one day.

In the system here described motorcoaches are inspected daily and drivers are required to report each day on the condition of vehicles driven by them. With these memoranda as a guide, more thorough examinations are made at intervals of 1000, 4000 and 8000 miles. Minor repairs are made in all garages, but where major adjustments are necessary the troublesome unit is replaced with another and taken to one central repair-station.

In this central shop are included provisions for machine work; engine assembly; rear axle, front axle, transmission, radiator, general chassis, and body repair; blacksmithing; sheet-metal work; and electrical and testing work. A large stock-room and offices also form part of the establishment. In addition to repairing, carried on according to the routine here described, the shop manufactures fenders, hoods, radiators, and batteries. Special precautions are taken to keep the stock parts at the minimum and yet complete and to maintain accurate and descriptive records.

Pneumatic Tires for Heavier Loads. By C. Macbeth. Reprint of paper presented before The Institution of Automobile Engineers. Published by The Institution of Automobile Engineers, London, England. 13 pp.; 4 illustrations.

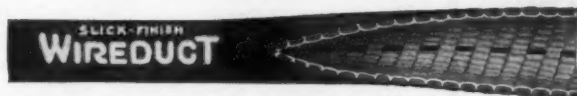
That all but very slow traffic should use pneumatic tires is the thesis of the author. He believes that the multiple-axle vehicle is desirable for total loads of 4 tons and more and that its use overcomes all but two obstacles to the application of pneumatics for the carrying of heavy loads: the high loading platform occasioned by them and the large wheel-diameters due to brake accommodation.

To make possible the wider application of pneumatic tires he suggests that the following changes in truck chassis and

(Continued on p. 36)

WIREDUCT

AUTO CABLE HOUSING



A Non-metallic Flexible Conduit
Designed Especially
for
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✓ Cadillac
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A compact homogeneous tube, scientifically designed and manufactured.

This conduit is a seamless spiral weave consisting of a helical member of tough, hard calendered fibre board, slit with such accuracy as to insure a close, firm structure, when interwoven with cotton warp strands.

The surface is treated with moisture and flame proof compounds in accordance with S. A. E. and Underwriters' Laboratories standards and coated with the celebrated "Slick Finish" making it clean to handle and neat in appearance.

Advantages:

Safety—Being non-metallic, it does not cause short circuits. On the contrary, it serves as just so much additional insulation.

Lightness—Reduced weight eliminates wear and tear on fastenings and terminals.

Assembly—It lays well, and is easy to work and clean to handle.

Appearance—The neat "Slick Finish" looks well on any car.

Rattle-proof Rust-proof

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Samples furnished upon request

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EXCLUSIVE SAFETY FEATURE

If the thermostatic element should get damaged, allowing the volatile liquid to escape, the valve will move to a position of safety, and the cooling water will flow unrestricted through the radiator

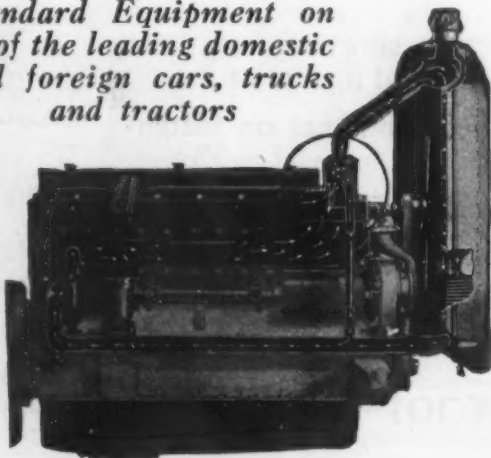
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Automatically controls the flow of cooling water through the engine, and thus maintains it at the most efficient temperature. This means more power with from 15 to 20% less gas consumption, as well as reduced wear on valves, pistons and cylinders, less crankcase dilution and decreased carbon deposits.

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NOTES AND REVIEWS

Continued

tire design be made: brakes and brake-gear, the differential and the major portion of the final reduction-gear be no longer unsprung; each wheel be independently connected to the chassis and have no lateral displacement in relation to it; wheels and tires of smaller diameter be used; and, for a given wheel load, tire sections be increased and inflation-pressures reduced.

A complete description is given of a proposed chassis embodying these ideas and designed to carry a 4-ton load, and eight reasons are advanced for fitting balloon-tire equipment to such a vehicle. Suggestions as to the proper low-pressure tires for heavier loads are also made.

Inlet and Exhaust Phenomena. By K. J. de Juhász. Published in *The Automobile Engineer*, October, 1926, p. 369.

In his investigation, aimed at the accurate measurement of the slight pressure variations during the pumping cycle of a high-speed engine, the author has faced a difficult technical problem. A de Juhász indicator was used in the experiments carried out at the heat-engines laboratory of the Hungarian Royal Technical College in Budapest, and a four-cylinder 1910 Benz automobile engine with a bore and stroke of 90 and 140 mm. (3.54 and 5.51 in.) respectively and a compression-ratio of 4.3 to 1.0.

Pressure-volume diagrams were taken at different loads, speeds and other conditions. The resultant diagrams together with the numerical values ascertained are given in detail. In addition to the extensive statement of the findings of the tests, the author presents an analysis of the diagrams from various viewpoints and the conclusions drawn. Some of the subjects covered in this way are the mechanical efficiency of the pumping cycle, the operation of the exhaust system, the application of the law of acoustics to pressure-wave phenomena, and the influence of exhaust-wave phenomena on engine-power. In conclusion the author emphasizes as a subject of interest an extensive research on the characteristics of high-speed supercharging engines.

The Strength of Gear Teeth. By S. Timoshenko and R. V. Baud. Published in *Mechanical Engineering*, November, 1926, p. 1105.

In this paper the authors discuss stresses in and deflections of gear-teeth. By using the photoelastic method the stress concentration at the tooth root has been studied and the factors thereof established for various radii of the fillet. The local stresses at the surface of contact of two teeth in mesh are discussed, using the Herz theory, and the most unfavorable conditions are shown to occur at some depth beneath the surface of contact. Equations are given for calculating the deflection of teeth, and this deflection, according to the results obtained, is usually less than the inaccuracies in commercial gears.

Le Rallye des Carburants Nationaux. Published in *A. C. F.*, October, 1926, p. 10.

To encourage interest in the development of fuels other than petroleum products, the Automobile Club of France organized the tour here described. The Royal Automobile Club of Belgium, the French Minister of War and national department of liquid fuels were also sponsors.

Of the 19 formal entries, 9 used producer gas as fuel; 2, acetylene; 2, acetylene with a diluent; 2, compressed methane; and 2, a commercial product the composition of which is not given. Vehicles making only part of the trip included two using a mixture of 50-per cent gasoline and 50-per cent dehydrated ethyl alcohol, and one burning a fuel the basic constituent of which was methyl alcohol.

Twelve days was consumed in making the trip, which was in the nature of a demonstration of what results could be obtained with fuels other than gasoline. Emphasis is laid,

(Continued on p. 38)



A REALLY FAST MAROON DUCO

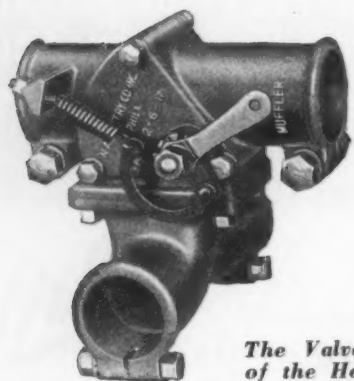
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THE Petry Bus Heating System with standard valve, fitting, bends, guards, hangers, insulations, etc., is the **ONLY** efficient **COMPLETE** system now offered.

Is easily applied and adaptable to the varied types of bus body and chassis construction.

Extremely light in weight, due to the use of special drawn light gauge steel tubing, the system is designed to withstand weaving, and road conditions encountered by the modern high-powered motor bus.

Radiator type 2-tube heater—made vertically or horizontally—is meeting with much favor *where the wheel house is of such construction as to make a bend over or around it difficult or objectionable.*

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NOTES AND REVIEWS

Continued

in the article, on the enthusiasm with which the cavalcade was received and the encouragement given to the research for gasoline substitutes.

Comment on Peut Supprimer L'Onde Explosive Dans les Moteurs D'Automobile. By Paul Dumanois. Published in *Omnia*, October, 1926, p. 397.

The explosive wave characteristic of detonation is caused, says the author, by a coincidence in time and space of the physical phenomenon of adiabatic pressure and the chemical phenomenon of instantaneous combustion caused by it. Anti-detonants such as tetraethyl lead prevent the explosive wave by acting on the chemical factor and increasing the time necessary to produce spontaneous combustion at a given temperature.

Is it not equally logical, questions the author to make the other, or physical phenomenon, the basis of anti-detonation study? The method is to create in the combustion-chamber in the direction of flame propagation gradations in section that will check the wave and destroy it. The author then recounts an experiment made on an engine of bore and stroke of 75 and 130 mm. (2.9527 and 5.1181 in.) respectively and with lateral ignition. A series of steps was superimposed on top of the piston, the lowest being nearest the point of ignition. The compression pressure was raised from 4.6 to 6.7 and combustion took place with complete absence of an explosive wave. The conclusion reached is that in the effort to secure high compression and economy, the architecture of the engine itself must be studied.

Future Trends in Automotive Fuels. By A. C. Fieldner and R. L. Brown. Published in *Industrial and Engineering Chemistry*, October, 1926, p. 1009.

Will the automobile industry, in the near or distant future, be limited either in size or in nature by the essential factor, fuel, and if so, how? The authors broadly survey the developments in both the petroleum and automotive industries, quoting many sources of information, and present their interpretations of present trends.

For the next 20 years, in their opinion, petroleum will continue to furnish the great bulk of automotive fuel. To justify their opinion they quote the improvements in crude-oil production and in refinery practice, the development of cracking, the use of anti-knock agents and more efficient carbureter, engine and motor-car design.

When the supply of petroleum becomes inadequate, liquid fuels that can be carbureted will still be demanded. They will be provided in the form of gasoline substitutes or augmenting materials obtained from the fermentation of vegetable matter, the distillation of oil shale, the carbonization and the hydrogenation of coal and lignite, and direct synthesis of alcohols and hydrocarbons from combustible gases. Fortunately, most of these substitute materials have high anti-detonating properties.

Eventualities that must not be overlooked are the return to steam power, the development of a light-weight battery and the consequent advance to general use of electrically driven vehicles and engines burning coal dust, heavy oils, coal tar or producer gas.

Two-Component Recording Accelerometer. Published in *Engineering*, Sept. 24, 1926, p. 396.

The instrument described, a commercial product, can record accelerations in two planes at right angles or in two directions at right angles in the same plane. It is portable, weighing about 22 lb. and being contained in a case 5 x 10 x 11 in.

Accelerations are marked on one side of a celluloid strip by styli, while time is marked on the back by a third stylus operated by an electromagnet. With the standard spring, the natural period of the acceleration-recording instrument

(Continued on p. 40)



IN the jungles of Asia and in the jungles of traffic, cable carries the load. In the one, stout stranded cable of twisted wires; in the other staunch automotive cable furnished by Graybar.

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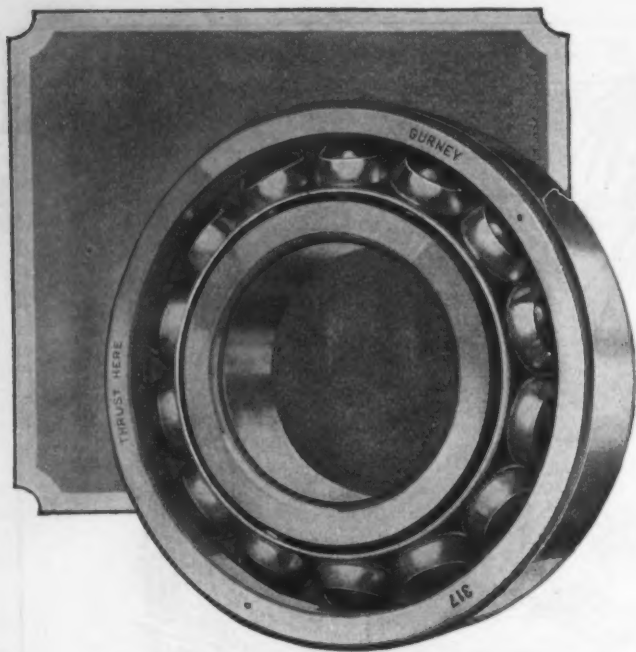
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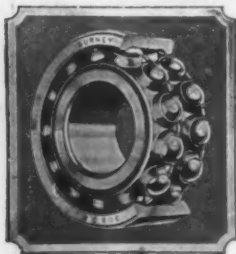
Successor to Western Electric Supply Dept.
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THE GRAYBAR TAG UNDER WHICH 60,000
QUALITY ELECTRICAL SUPPLIES ARE SHIPPED



Better Bearings for every use!



Molybdenum Steel Balls are now used in all types of Gurney Ball Bearings. This increases their capacities even more than during the past 24 years, during which time they have been rated higher than all other bearings.

New Data Sheets—just issued—will give you complete information. Write.



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Gurney Ball Bearing Division
JAMESTOWN, N. Y.

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BALL BEARINGS

NOTES AND REVIEWS

Continued

is about 0.056 sec. and an acceleration equal to that of gravity produces a movement of the stylus of 1 mm. (0.0394 in.). According to the claims set forth, accelerations of the order of 4 in. per sec. per sec. can be measured accurately.

An Instrument for the Measurement of Relative Road Roughness. Published in *Public Roads*, September, 1926, p. 144.

A rack attached in a vertical position to the front axle of the vehicle is the central part of the roughometer developed by the Bureau of Public Roads. Meshed with this rack is a spur-gear supported by the frame of the car. Movement of the front axle with respect to the chassis, caused by deflection of the body springs, produces translation of the rack and rotation of the gear. This gear is connected through a flexible shaft to a mechanical counter that records the spring movement. The counter is arranged so that it does not operate when the springs return from their deflected position. The record made, or the roughness factor, is the sum of all the spring deflections in the time this instrument is attached to the car.

An account is given of road trials that are said to have proved the utility of the instrument and criteria are set forth for the interpretation of the roughness factor.

Laboratory Manual of Testing Materials. By William Kendrick Hatt and H. H. Scofield. Published by McGraw-Hill Book Co., Inc. 182 pp.; 35 illustrations.

Of the fundamental facts that form the basis of engineering practice, the characteristics of materials bulk large in significance. Almost as important as the characteristics themselves is the knowledge of how they can be accurately ascertained, what their general nature is, what instruments or machines have been evolved to measure them, and the precautions that should be taken in operating such machines to avoid erroneous findings.

The present volume takes for its subject part of this broad general field and outlines briefly laboratory technique to be used in testing materials. It is intended chiefly for the student but it will serve as a helpful aid to the practitioner who is beginning work in this branch or who wants a clear, simple outline of laboratory practice. The material presented is based on the experience through many years of the laboratory for testing materials of Purdue University. The present volume is the third edition, the first having been issued in 1913.

A few specific prerequisites to laboratory work are set down in the first chapter, after which instructions are given for writing reports. The limiting criteria on the strength of materials are defined, and then testing machines and methods of operating them are described. A list of suggested experiments is given and finally instructions are laid down for performing experiments on testing machines, iron and steel, wood, cements, aggregates, and on road materials; and proportioning mortars and concretes.

A Comparison of Static and Dynamic Tensile and Notched-Bar Tests. By Kôtarô Honda. Published in *Engineering*, Sept. 24, 1926, p. 398.

In the Research Institute for Iron, Steel and Other Metals, Sendai, Japan, an investigation has been begun into the merits of machines for testing materials. This article is a preliminary report of the project.

The energy required to break a test-piece, both slowly and suddenly, is defined theoretically, and then an actual case is cited of the breaking of a test-piece by a tensile-strength or bending-test machine. The energy required was found to be larger than that arrived at theoretically, due to the absorption of work in the deformation of the test-piece. Reference is made to attempts now being made at the Research Institute to measure the energy of internal strain of a piece undergoing test.

(Continued on p. 42)

More Gear Tooth Grinders

TIME was when several careful and expensive operations were necessary in gear tooth finishing.

Even with care, considerable spoilage resulted. This spoilage was reclaimed by grinding.

Now, however, the Walcott Gear Tooth Grinder has eliminated the need of progressive finishing. The highest grades of gears are being ground accurately, rapidly and economically at a single operation.

And manufacturers are availing themselves of this new production facility.

The Walcott Grinder is self-contained and very compact, requiring but six feet square of floor

space. It is very economical to operate. Capable of finishing both sides of all teeth, or may be installed in pairs, one operator easily handling two machines.

Large machine shops everywhere are installing—it will pay you to investigate.

WALCOTT MACHINE CO.

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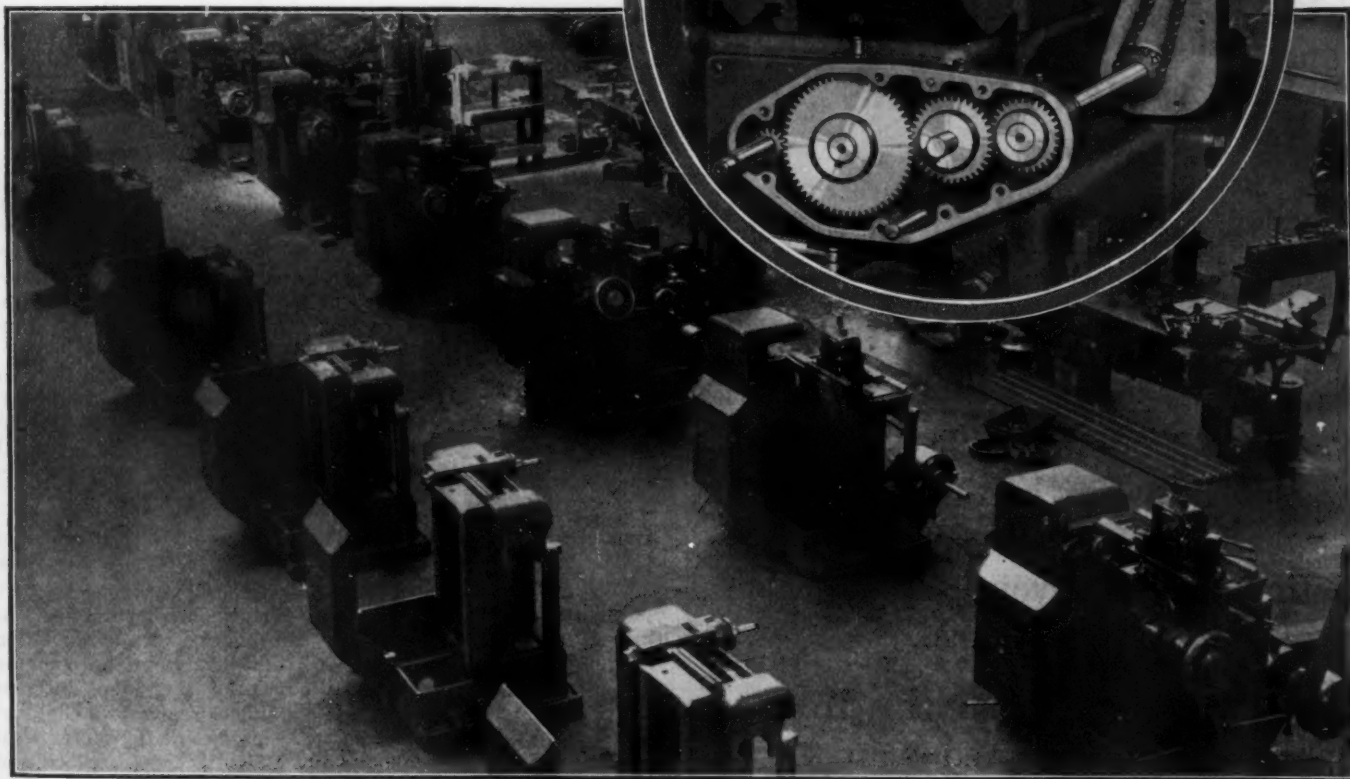
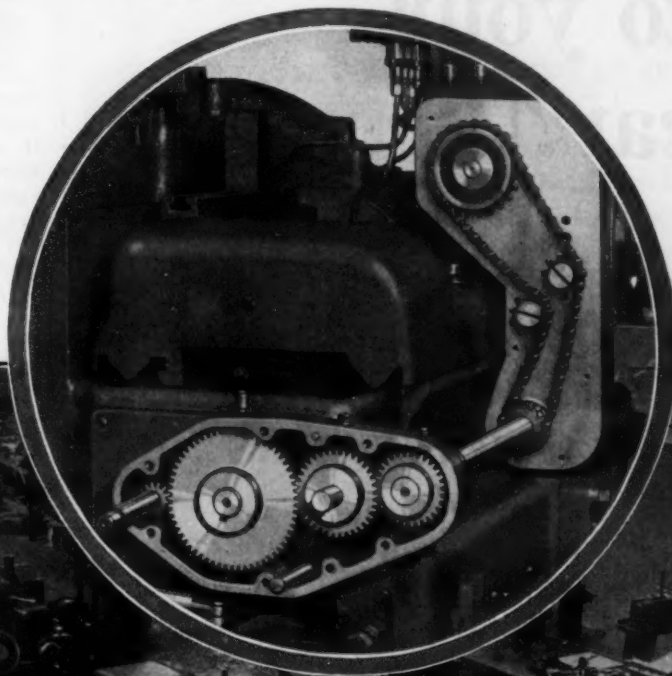
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Photographs, estimates of probable production, and full details will be supplied when requested.

Illustrating quantity production methods employed in producing Walcott Tooth Grinders; insuring uniform quality. The Walcott is very substantially constructed throughout, for years of service.

Inset shows right hand side of machine with cover removed. Note chain drive and right hand end of work carriage.



Precision Machines for the Automotive Industry

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Solid BRASS or BRONZE hardware never rusts and is a permanent asset to a car.

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NOTES AND REVIEWS

Continued

In discussing the relation between static and dynamic tests the author states that in tension tests the energy absorbed is less for the former than the latter, while in bending tests it is the same and that the absorbed energy in the impact test is independent of the hammer velocity. Experimental results obtained at the Research Institute are cited in support of these three conclusions.

A method of measuring the degree of fatigue in repeated impact-tests is described, and curves are plotted showing the relation between fatigue and number of impacts for a test-specimen of annealed 0.3-per cent carbon steel.

Research Work at Bureau of Standards. By H. W. Gillett. Published in *Forging-Stamping-Heat Treating*, October, 1926, p. 368.

Duralumin is subject to embrittlement due to intercrystalline attack, a type of corrosion. While deterioration from this cause was not responsible for the wreck of the Shenandoah, it can, if it advances too far, be dangerous. Certain expedients have been suggested for preventing or guarding against such embrittlement and the value of these is being determined by exposure tests.

This is one of the new developments associated with a Bureau of Standards research project that has not yet been covered by a report. Other hitherto unpublished findings are published in this article, which is a brief summary of the metallurgical activities of the Bureau of Standards during the last year. Reports issued in the last 12 months are also listed and the projects now under way are enumerated, classified according to their progress toward completion.

Notes on the Induction Motor. By H. E. Dance. Published by the Oxford University Press, New York City. 152 pp.; 70 illustrations.

In this book the author has aimed to present a complete approximate theory of the induction motor, for the reader who does not wish to study the machine from the designer's point of view. Introductory notes on starting, speed control and power-factor are also included. In treatment, familiarity on the part of the reader with the mechanical details of the induction motor and with the more common type of alternating-current windings is assumed.

Three sections make up the book: one dealing with the production of the rotating magnetic field by alternating currents in polyphase windings, another with the behavior of conductors in a constant-rotating sinusoidal field and the last with the combination of the results thus arrived at to the theory of the machine as a whole.

Airmen and Aircraft. By Henry H. Arnold. Published by The Ronald Press Co., New York City. 216 pp.; 18 illustrations.

Twenty years ago when the Wright brothers tried out their new airplane at Dayton, an undertaker, symbolizing the doubting public, attended each flight. Now the common sight of flying craft has instilled a more confident interest in the public; aeronautics has expanded beyond the field of technicians and has become a topic of interest to the general reader. This book is an attempt to satisfy the curiosity of the enthusiastic youth and the uninitiated adult on some of the main points of aerodynamics and aviation.

That Leonardo di Vinci, in 1500, made aircraft models that lifted themselves into the air mechanically without employing light gases is one of the interesting points cited in the brief review of the history of aviation. In explaining aerostatics non-technically, the ascent of a balloon is likened to the action of a piece of wood in rising to the surface of water after it has been submerged and released. Lift and drag are defined by a comparison with the effect on an inclined lead plate of being struck from the under side by a heavy weight.

(Continued on p. 44)

HOT FORGED

From Molybdenum Steel



IN the first place, the balls which go into SRB Bearings won their reputation long ago...established it, in years spent speeding up and lightening the loads of machines in factory shops.

In the second place, these balls are now made from the newer, tougher, longer-lasting Molybdenum Steel...a steel which proved its resistance in shell-battered army tanks during the war. Durable as SRB Bearings were...this added still more years to their lives...



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at least 25% more in actual performance.

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HOT FORGED

into balls under Bradley Hammers, a process known by all metallurgists to improve the grain structure of steel...to shape it with minimum strain...to toughen it...to strengthen it.

Now! Add point to point and you will specify, not alone ball bearings, but SRB Bearings with Balls Hot Forged from Molybdenum Steel.



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Standard Sales and Service Company,
Plainville, Conn., with direct factory
branches at New York, Cleveland,
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for the cars that
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Ask
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he will say
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NOTES AND REVIEWS

Concluded

An examination is made of the ways in which airplanes have been made useful, both in war and in peace. For the benefit of young men interested in aviation to the extent of making it their occupation, an account is given of the requirements and the training for Army pilots. Stories of some epochal flights and of some of aviation's heroes are also set forth.

All the World's Aircraft. By C. G. Grey and Leonard Bridgman. Published by Sampson Low, Marston & Co., Ltd., London. 459 pp.

Justifying its title, this book, a yearly edition, covers the aeronautical affairs of no less than 50 countries, including such national units as Esthonia, Finland, Latvia, Lithuania, and Siam as well as the empires that loom more largely in the world's affairs.

In the first, or historical section, the progress of aviation during the year ended July, 1926, is summarized in a standardized form so that one country can be compared with another and so that a unified history for a long period of time can be easily obtained from the successive editions of the book. The information in this section was obtained for the most part from the answers to questionnaires sent to authorities in each country. Besides tracing the developments in military, naval and civil aeronautics, the editors have compiled the names and addresses of aeronautical officials, departments, associations, and publications of the various nations.

In the second section are described airplanes built throughout the world, grouped according to the nationality of the builder. Twenty-one of the 50 countries do not make an appearance in this section as they are not known to build aircraft. A third section deals in a similar way with aircraft engines and a fourth, with airships. An index to the airplane, engine and airship sections makes it easy for a reader interested in particular items to find the information desired, as it lists the official and informal names of builders and the names and call letters of aircraft.

The Effect of Reduced Intake-Air Pressure and of Hydrogen on the Performance of a Solid-Injection Oil-Engine. By G. F. Mucklow. Preprint of paper presented before The Institution of Automobile Engineers and The Royal Aeronautical Society. Published by The Institution of Automobile Engineers, London, England. 47 pp.; 13 illustrations.

In an airship in flight, as the supply of oil fuel is consumed, a corresponding weight of hydrogen must be released. Can this waste gas be utilized to replace a portion of the oil fuel supplied to the engine is the question that the author endeavors to answer. He describes a series of experiments carried out at the University of Manchester on a Crossley solid-injection oil-engine in which small volumes of hydrogen or coal-gas were introduced along with the air supply to the engine. Within the range of the experiments, the addition of the gas did not interfere with satisfactory engine-operation, although at constant load and speed it did slightly reduce thermal efficiency.

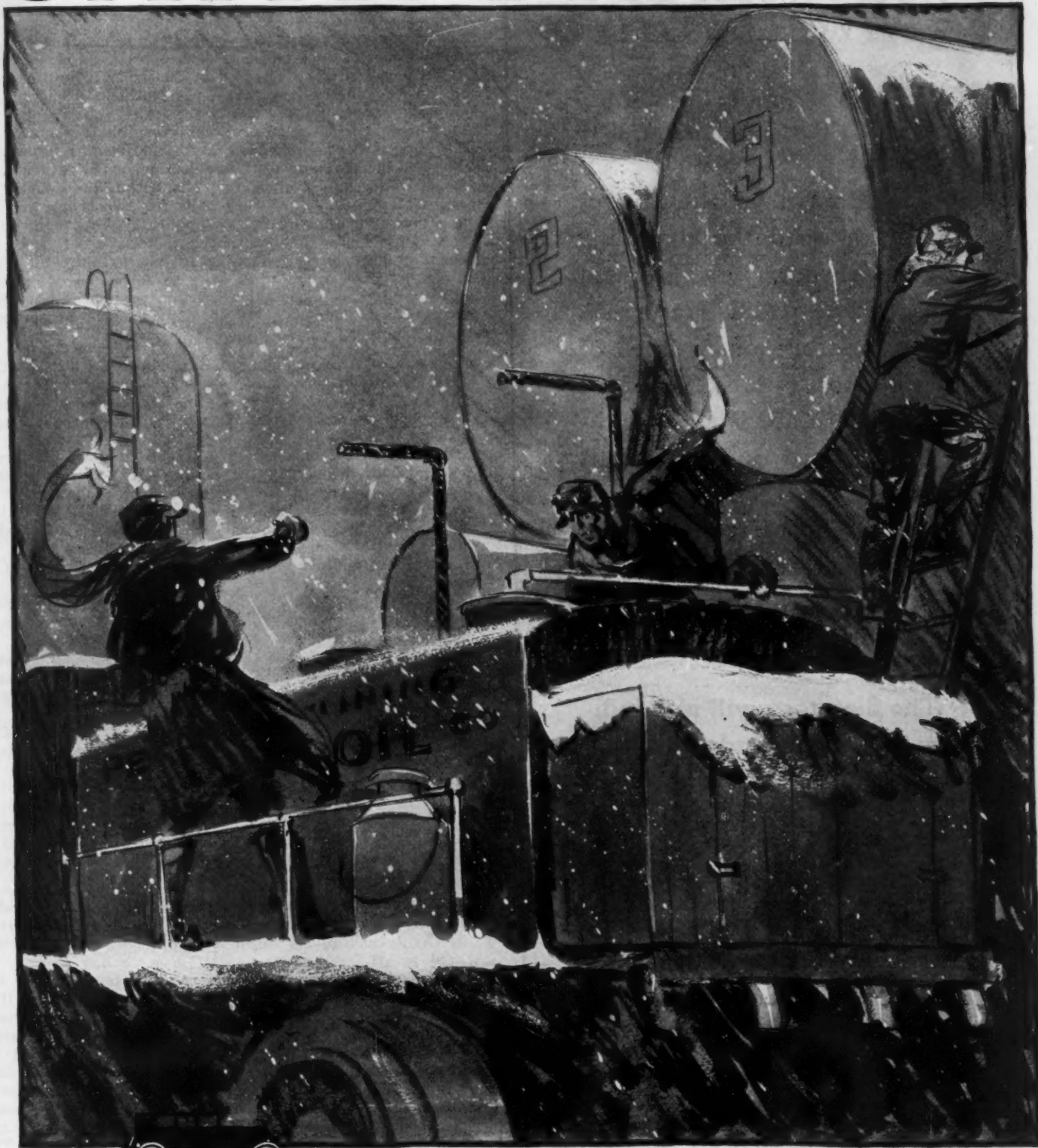
In the second section of the paper are described experiments to determine the effects produced on the performance of a solid-injection oil-engine by throttling the air intake. From the results obtained the performance of the engine under altitude conditions is predicted.

Research on Oil-Injection Engines for Aircraft. By William F. Joachim. Published in *Mechanical Engineering*, November, 1926, p. 1123.

As a preface to the main body of his paper, the author points out some of the difficulties in the way of solving the

(Continued on p. 46)

SMITH FRAMES



THE development of the automobile from the plaything of yesteryear to the dependable servant of mankind that it is today, is a story of engineering progress—a story through which the name Smith has ever marked the greatest advance in frame design.

A. O. SMITH CORPORATION • MILWAUKEE, WISCONSIN
DETROIT OFFICE: GENERAL MOTORS BLDG.

ANNOUNCING

"Sources of Supply for S. A. E. Standard Parts and Materials"

The Council of the Society has authorized the compiling and publication in the next issue of the S.A.E. Handbook of a directory of Sources of Supply for S.A.E. Standard Parts and Materials. This directory, based on the present Index to Advertisers' Products, will include all manufacturers filing with the Society certificates signed by the proper officials.

The directory will also indicate the parts and materials carried in stock by the different manufacturers.

The value of this directory to the engineers and purchasing agents using the S.A.E. Handbook will be appreciated. It will be the first of its kind ever compiled. It exemplifies the trend in standardization activities as evidenced by the recent action of the U. S. Federal Specifications Board and the American Engineering Standards Committee.

NOTES AND REVIEWS

Continued

two major problems of the aircraft oil-injection engine, the early ignition and the complete combustion of the fuel early in the power stroke. The rest of the paper is devoted to the oil-injection engine research of the National Advisory Committee for Aeronautics.

Of a fundamental nature, this research is planned with the idea of developing basic and experimental information that will lead to more efficient injection, vaporization, distribution and combustion of fuel oils within the cylinders of aircraft engines. This work calls for the design and construction of special laboratory apparatus for the investigation of hydraulics and of the characteristics of fuels. By means of high-speed motion-picture photography, oil sprays in dense gases are studied; the performance of injection valves and miscellaneous oil-injection equipment is studied; and tests are made of cylinders, cylinder-heads and oil-injection systems on single-cylinder test engines.

The Drag of Airships; Drag of Bare Hulls. Part 2. By Clinton H. Havill. National Advisory Committee for Aeronautics Technical Note No. 248. Published by National Advisory Committee for Aeronautics, City of Washington. 15 pp.

The reason for this research was to furnish the airship designer with a method for finding the VL curve, where L = length in feet of the particular form of hull and V = air speed in feet per second of any conventional type of hull, using data obtained from actual performance of airships flown prior to 1926.

Among the findings listed as the outstanding results of the work are:

- (1) An empirical method for finding the drag coefficient of any bare airship hull with its VL curve from 100,000 to 6,400,000-cu. ft. volume
- (2) The derivation of an empirical shape coefficient that can be calculated from the hull contour that defines the VL curve of any conventional airship shape within certain limits placed
- (3) The determination that (a) the slope of each VL curve differs with each type of hull and that its slope is not entirely constant; (b) C_H = function of $(VL)^n$, where C_H = drag coefficient of bare airship hull and n is a variable at different values of VL ; and (c) the value of n varies slowly so that extrapolations beyond that given by the diagrams presented of the VL curve are not much in error

A Review of the Present Position with Regard to Airship Research and Experiment. By V. C. Richmond. Published in *The Journal of the Royal Aeronautical Society*, October, 1926, p. 547.

An interesting section of this paper, a summary of the present status of airship research in Great Britain, is that dealing with the instruments used in the full-scale investigation of internal stress distribution in the hull framework of a rigid airship. Each instrument is in effect an extensometer, in which the changes in length of the girders or wire bracings under varying loads can be measured at a distance. Each instrument consists of a number of elements that can be assembled in different ways according to the purpose for which the instrument may be required. The principal part is the electric choke coil with variable air-gap, by which is measured the extension or compression. When an alternating current of constant ratio of voltage to frequency is applied, the reactance and consequently the current through the electromagnet varies linearly with the air-gap and hence with the strain in the member. Three methods of measuring the current are given. Developments in America in this type of research are described briefly and commended, and some applications of the use of the instruments in full-scale investigations are set forth.

(Concluded on p. 48)

HASKELITE

HASKELITE, the structural plywood, cemented together by special patented process providing almost unbreakable bond. Ideal for roofs, head lining, etc.

Save 628 lbs. dead load



*Saving in Weight on a 29 Passenger Bus
Through the use of HASKELITE and
PLYMETL*

Type of HASKELITE and PLYMETL and Its Application in the Bus	Sq. Ft.	Wt.	Replaces	Sq. Ft.	Wt.	Pounds Saved
$\frac{1}{8}$ " HASKELITE Roof	161	143	$\frac{3}{8}$ " Poplar Slats	161	286	143
$\frac{1}{4}$ " VE PLYMETL Side Panels	125	172	20 gauge steel	125	255	
			$\frac{1}{4}$ " Plywood lining	120	87	
$\frac{3}{4}$ " HASKELITE Floor	139	293	$1\frac{1}{4}$ " Pine	139	608	315
TOTAL SAVING						628

PLYMETL, steel faced HASKELITE, combines strength and lightweight with resistance to abrasion and indentation. Ideal for side panels.

PLYMETL

SAEJ12-Gray

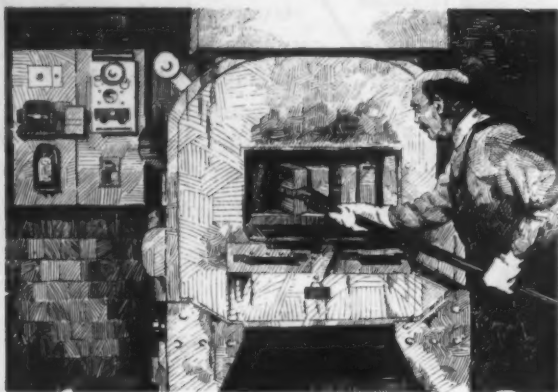
SURPLUS weight in a bus body adds proportionately to gas consumption, tire wear, etc. It produces no compensating revenue. Naturally you want to cut body weight to the lowest possible point without sacrificing strength, safety, long life, or appearance.

HASKELITE and PLYMETL are unique in combining lightweight with all these other advantages. In addition to cutting 628 pounds from the weight of the bus considered in the accompanying table, the adoption of HASKELITE and PLYMETL has actually made a better bus in its ability to resist accidents, in its length of life, in the ease of construction and repair, in both exterior and interior attractiveness, etc.

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Esdorn Lumber Company, Leggett and Barry Sts., New York City
Shadbolt & Boyd Iron Co., Milwaukee, Wis.
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Railway and Power Engineering Corporation, Ltd.
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Automatic Control of Temperature by Potentiometric Pyrometers

The Wilson-Maeulen Controller now coming into extensive use has been used in a number of plants for over two years and has been found remarkably dependable and free from breakdowns. It is of the very highest order of precision. Its husky standard motor is located outside the case.

WILSON-MAEULEN COMPANY INC

387 Concord Avenue

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NOTES AND REVIEWS

Concluded

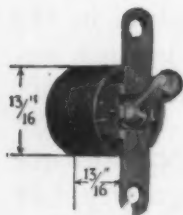
In addition to full-scale investigation of internal stress distribution, theoretical and model research is reviewed. The three types of investigation into the external forces acting upon an airship are also discussed. In an appendix is given a mathematical analysis of the effect of certain simple wind variations on the lateral force exerted at the bow of the R33 when moored.

The Tailless Airplane. By G. T. R. Hill. Published in *The Journal of the Royal Aeronautical Society*, September, 1926, p. 519.

Three years of scientific and practical work, the results of which are embodied in the Pterodactyl tailless monoplane, are summarized in this article. The author tells of the speculation leading to this conception of a better-controlled airplane, the embodiment of these ideas in an airplane arranged as a glider, the checking of theoretical expectations through tests of this and of models and finally the installation of an engine.

A detailed description of the airplane in its final state is given. The claim is made that, when the inertia of the control system has been reduced, the control will be an improvement on that of any existing airplane. Three other advantages are attributed to this type: construction for a percentage structure weight smaller than the normal; possibility of reversion to the pusher type without loss of performance; and the opportunity for improvement in the general arrangement of the flying boat. The author's vision of the future includes the application of the tailless principle to a larger, biplane structure; reduction of head resistance; and the escape from natural limits through the ideas on which he has been working.

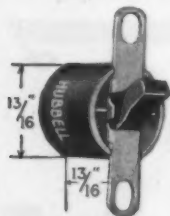
HUBBELL Toggle Switches



No. 8250



No. 8250 with
No. 8251 Plate



No. 8270

Quickly and Easily Installed

Just bore a $\frac{7}{8}$ " hole and insert switch. Easily wired—binding screws are large and very accessible.

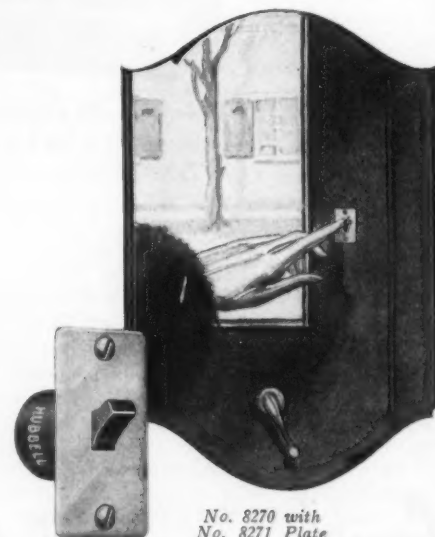
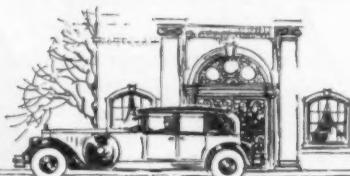
Equipped with strong, easily-operated toggle mechanism with smooth, positive action.

A high-grade switch of simple, durable construction, adapted for speedy installation requirements.

Flush and recessed types. Plates in any finish.

Write for samples. See how well-made these switches are and how quickly they can be installed.

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No. 8270 with
No. 8271 Plate

Every day more motorists learn that they can purchase cars with the All-Steel Body at a cost no greater than is asked for cars which *do not* afford this protection. This rapidly spreading knowledge is making the job of some salesman easier—the job of others increasingly difficult. In which group are you?

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EGYPTIAN



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THERE are other factors that may be more important to be sure, but to the appearance falls a large proportion of the responsibility for the selling success of the car. That is one reason why motor car manufacturers are depending more and more on Egyptian Lacquer—a product used for fifty years in other lines.

The Egyptian Lacquer Mfg. Co.
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LACQUERS

Add a Lasting Thrill to any Motor



Bohn Products include Ring True Bearings—Bohnalite Castings, semi-permanent, permanent mold and sand, Nelson Bohnalite pistons; we also supply the government with replacement pistons and bearings for the Liberty engine.

THE LIGHT ALLOY PISTON WITH A STEEL BACKBONE

It's Skirt **HOBbled** *with Steel*



The Strut

Special Alloy steel struts are cast in, to control expansion and maintain satisfactory clearances under all engine operating conditions. The struts are the backbone of piston endurance and life.

★ Bohnalite, the light alloy from which this piston is made, should never be confused with any other aluminum alloy on the market. Every Nelson Bohnalite Piston is heat-treated for uniformity, strength and hardness.

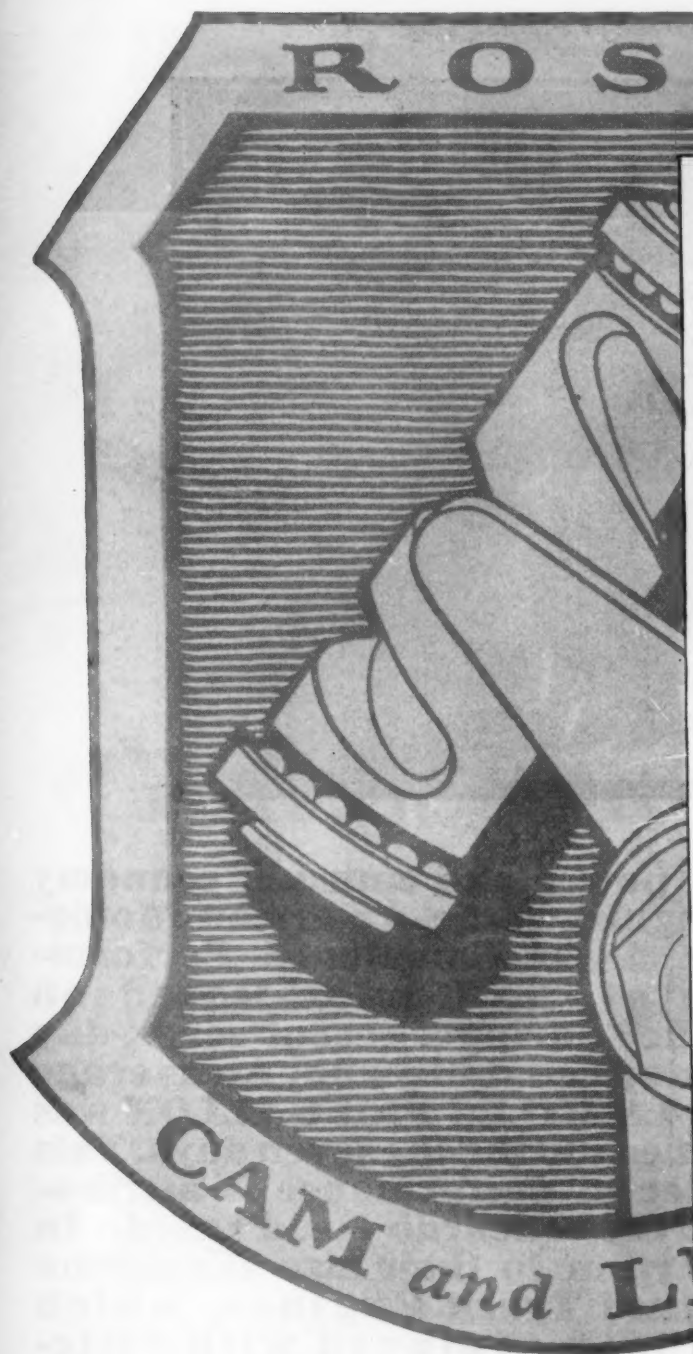
Torn between two evils—light alloy pistons have had to be either fitted loosely to take care of expansion, or if fitted closely, excessive wear and scored pistons resulted.

In the case of the Nelson★ Bohnalite Piston, the skirt (the limiting dimension of any piston) has been hobbled with steel, which makes it possible to fit this light alloy piston to very close dimensions and still get very long life. (50,000 miles and more)

Combined in this one piston are all of the advantages ever claimed for cast iron or light alloy pistons.

Nelson Bohnalite Pistons are already being used by manufacturers of cars, for which they make claims of unprecedented performance—a list of them will be gladly furnished upon request, along with a booklet which further describes the design of this outstanding piston.

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DECEMBER 4, 1926



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The truck on a road-construction job has to make its own road—must force its way, heavily loaded with materials, over soft, loose, rutty, muddy, uneven ground! Hard going—and harder steering! The Ross Cam and Lever Steering Gear makes steering twice as easy under this and all other conditions—holds the wheels steady and true in soft loose, earth, sand and gravel, prevents ruts and bumps from jerking the steering wheel . . . That is why Ross is standard equipment on more makes of trucks than any other gear—likewise on cars and buses. Best for trucks and buses—best for your car, too! Drive a Ross-equipped car once and you'll have no other.

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You know you can do things, and easily, with a lever, that are wholly impossible without one. The long lever in the Ross Cam and Lever Steering Gear is one reason for the tremendous power that makes Ross Steering so easy. And the cam, with its variable pitch, constitutes the almost impassable barrier to road shock, that makes Ross steering so safe and so comfortable.

Mail the coupon below for FREE booklet "Efficiency in Steering" and list of Ross-equipped cars, buses and trucks.

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ROSS
 CAM and LEVER  **STEERING GEARS**

EASIER STEERING • LESS ROAD SHOCK

ROSS GEAR AND TOOL COMPANY, Lafayette, Indiana

Please send me your FREE booklet, "Efficiency in Steering", which explains fully the Ross Cam and Lever principle.

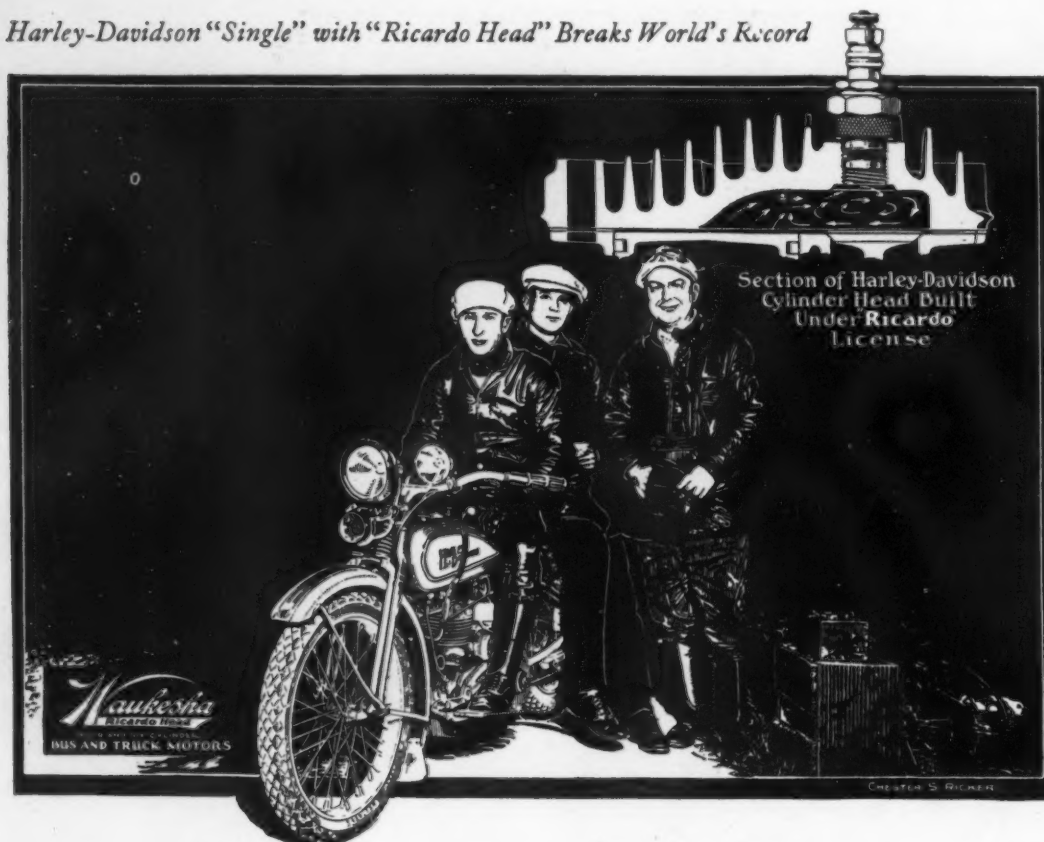
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Harley-Davidson "Single" with "Ricardo Head" Breaks World's Record



Ricardo Heads Put Miles in Gasoline

High power and unusual economy distinguished the American Motorcycle Ass'n Sanctioned Performance of the Harley-Davidson "Single" during a recent seven-day non-stop reliability run. An average of 124.8 MILES PER GALLON was obtained during the seven days. This wonderful performance is attributed to the "Ricardo Head" used. In proportion to their size Waukesha Bus and Truck Engines, which have been equipped with "Ricardo Heads" for over three years, give equal economy and power.

Power without "Ping" is another feature of all Waukesha "Ricardo Head" Engines. Write for "Six Cylinder Booklets" describing both large and small Bus and Truck Engines which are built in five sizes from 75 to 125 H. P.

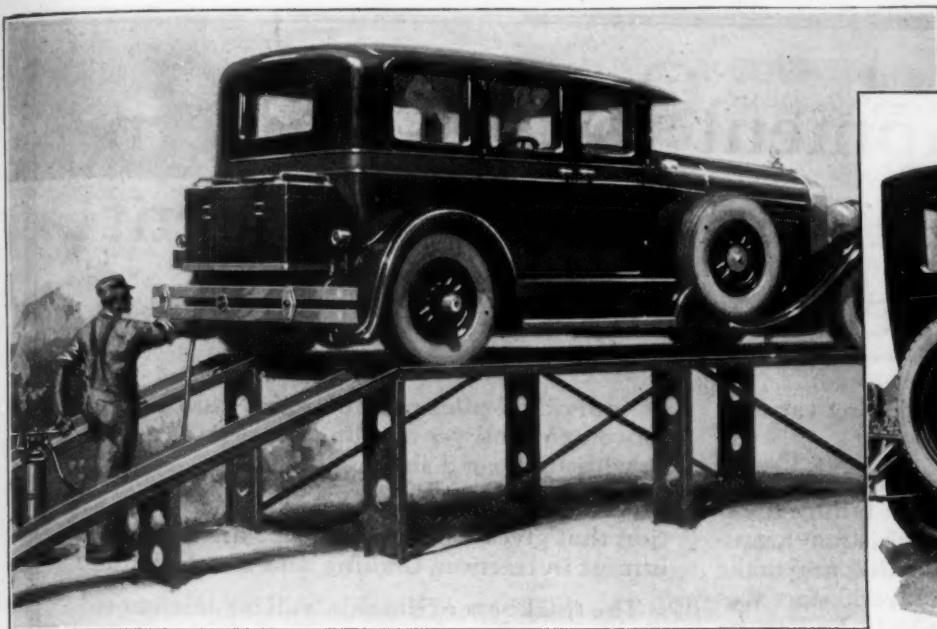
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You double your car's chances for care and service—*when it is Alemite equipped*

This is why

When a man buys a car he does so because he believes it will serve him *continuously*, and insofar as repairs are concerned, *cheaply*.

Yet a recent investigation showed that 80% of car troubles are due to careless or neglected lubrication. A cause over which you have no control.

The Alemite or Alemite-Zerk High Pressure Lubricating Systems double your car's chances of receiving proper care. This is why.

The owner of your car can easily lubri-

cate it himself. Or, he can drive it into any of the 40,000 Alemite Service Stations and receive expert service at a nominal charge.

We are telling the owners of your car the value of methodical lubrication. How by lubricating regularly they can cut their repair costs 80%—and lower the operating costs of their car 1 cent to 1½ cents a mile. Make it easy for them to lubricate. Thus you will benefit by *repeat* sales from satisfied owners.

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Service for cars
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Tire Equipment for the Modern Motorcoach—An Accomplishment in Specific Tire Design

PUTTING windows in a moving van will no longer make a motorcoach.

To consider the modern motorcoach as an evolution of a motortruck is a failure to realize the *specific* demands of this new transportation. The old box body did not make up the lacking elements. A fresh start was required. A new type of vehicle had to be constructed.

With this in mind, it is not reasonable to expect the old pneumatic truck tire to be adequate to the requirements of the motorcoach. Nor can an adaptation of a passenger car tire fill the need.

The United States Rubber Company early realized this. Their best trained experts—pioneers in the pneumatic bus tire field—were put on the problem. They studied motorcoach operation everywhere.

The result was a new type of tire in the industry—the Royal Cord Motorcoach Tire. Not an old tire with a new name, but a complete, new development, fully rounded out to fit the new requirements.

The Royal Cord Motorcoach Tire is an achievement in engineering. It embodies real advancements in tire construction. Note the following special features—

Latex-treated Web Cord—a carcass construction with flexibility unrestricted by cross-tie threads.

Sprayed Rubber—a rubber direct from virgin latex, free from all undesirable impurities, and with uniformity controlled to the dot.

A multi-ply carcass, more than enough to withstand all carcass strains, yet flexible enough to allow full freedom of carcass distortion, a measure of riding ease, a generous separation

of individual plies providing freedom of ply movement and yet banding the plies as a unit to withstand road shocks.

A liberal thickness of tread and a configuration that gives a full road grip, assuring the utmost in traction, braking and acceleration.

The thickness of the side wall is sufficient to protect against curb cutting and chafing.

Self-cooling bead construction, reducing to the minimum tire failure due to excessive heat accumulation. The bead wire is encased in hard rubber, a construction making for greater flexibility and ease of tire application.

A special moulded rubber and fabric flap affords complete protection against tube failure due to shifting, pinching or improper flap application.

United States Rubber Company

Trade  Mark



UNITED STATES
ROYAL CORD
Motorcoach

Some Job!

OF COURSE your customers dislike it—the messy spot-by-spot method of lubricating an automobile chassis. They are tired of hunting out each grease nipple and dopping it by hand.

Why not give them Bijur Lubrication—the simple, positive, reliable system of lubricating the entire chassis in a moment's time?

The Bijur System is standard on all 1925-1926 Packards. Motorists know how well it does its work, summer or winter, rain or shine. They are going to want Bijur Lubrication on the next cars they buy. Will yours have it for them?

The Bijur System is simplicity itself. Drip Plugs—one at each oiling point are connected by the simplest possible piping to an oil reservoir and gun on the dash.

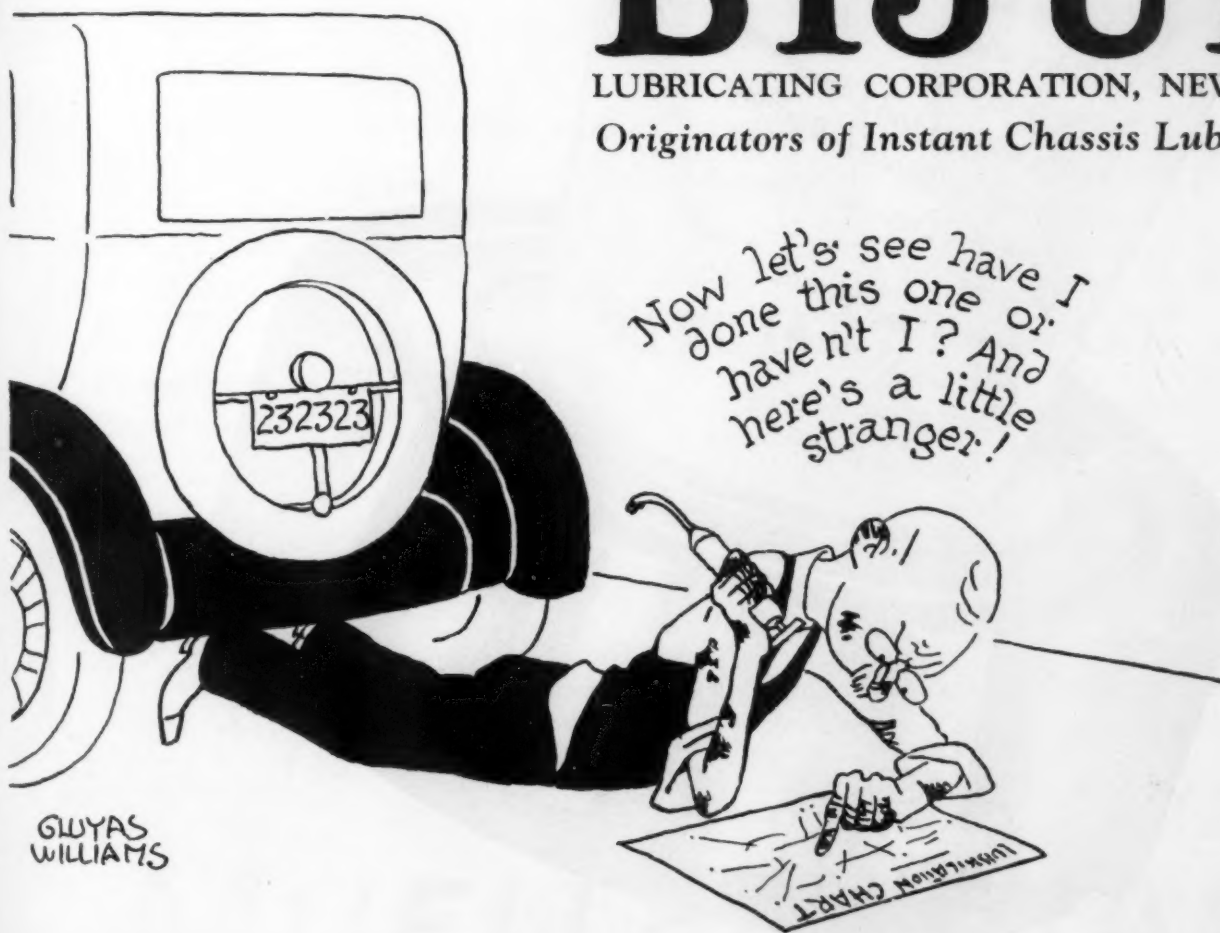
One pull of the gun handle puts the oil line under pressure and the Drip Plugs deposit a measured quantity of oil in the center of each bearing. That's all there is to it. No moving parts. Nothing to get out of order. Nothing to wear out.

Without obligation to you our Engineering Staff will gladly assist in redesigning chassis parts to accommodate the Bijur System.

BIJUR

LUBRICATING CORPORATION, NEW YORK

Originators of Instant Chassis Lubrication



GUYAS
WILLIAMS

Note the Table of Contents

110 pages of bearing data, recommendations and *knowledge*, based upon experience with 160,000,000 successfully applied bearings! That's the new Timken Engineering Journal, complete with figures and facts which are governing the adoption of Timken Bearings for every type of mechanical device, throughout industry.

New curves of endurance, output, and economy are being charted by means of Timken tapered design, Timken *POSITIVELY ALIGNED ROLLS*, and Timken-made steel, among the many Timken features. The Timken Engineering Journal tells exactly *why* and *how*. Your request on your letterhead brings your copy.

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Technical information regarding bearing sizes and their mountings can be secured from the Timken Roller Bearing Service & Sales Company's Branches located in the following cities: Atlanta, Boston, Buffalo, Chicago, Cincinnati, Cleveland, Dallas, Denver, Detroit, Kansas City, Los Angeles, Memphis, Milwaukee, Minneapolis, Newark, New York, Omaha, Philadelphia, Pittsburgh, Richmond, St. Louis, San Francisco, Seattle, Toronto, Winnipeg.



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in automotive parts and accessories
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RELLEUM BRASS FORGINGS

More and more Relleum Brass Forgings
are being specified for automotive parts
that must be strong, dense, uniform and
corrosion-resisting—the vital spots of the
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*Submit blue prints or samples and we will tell you
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Thread Tap for automotive work.*

To make a tool like this....

To make a tool to extremely close dimensions, that shall be strong, uniformly tempered, durable, and which has a splendid finish and a keen, lasting cutting edge, is no job for an amateur.

It requires real technical ability and craftsmanship—equipment of the finest—and above all, experience. These we have, and they are so organized and applied that the customer gets better value—*less cost per tapped hole*.

Much original creative work has been and is now being done by Threadwell

in the making of threading tools, for just one reason—to produce *accurate*, satisfactory taps in quantities sufficient to meet the needs of our customers. In other words, making a commercial necessity by mass production methods, yet retaining the close dimensions formerly found only in the laboratory.

Threadwell Taps have the qualities most desired in taps. It is *not* necessary to pay a premium for the greater accuracy and generally better results you get from their use. Let us tell you why.

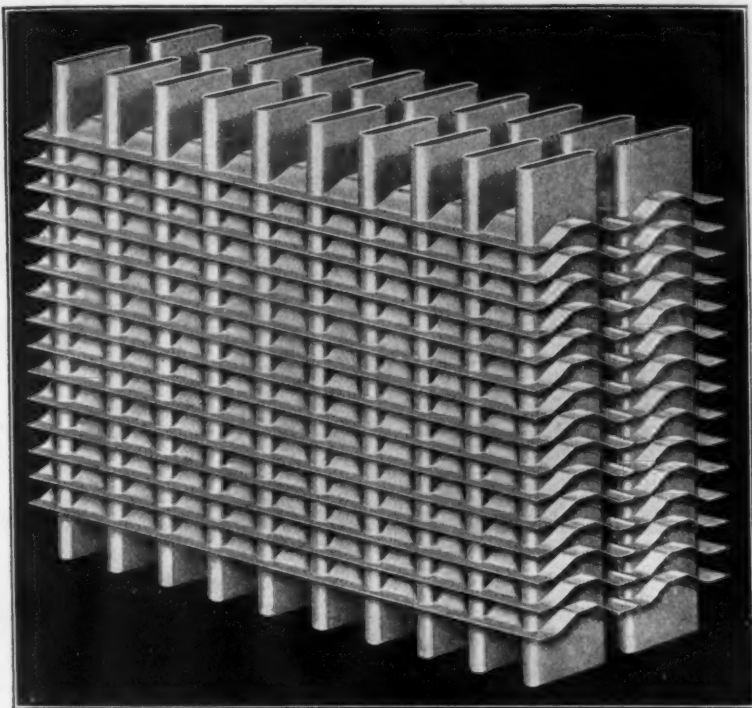
THE THREADWELL TOOL COMPANY GREENFIELD, MASS.

1323 Dime Bank Building.....	Detroit, Mich.	18 S. Clinton St.....	Chicago, Ill.
135 St. Clair Ave., N. E.....	Cleveland, Ohio	604 Mission St.....	San Francisco, Cal.
26 Cortlandt St.....	New York, N. Y.	246 St. Paul St.....	Rochester, N. Y.
Bessemer Building.....	Pittsburgh, Pa.	230 South Penn St.....	Indianapolis, Ind.
		1410 Porter St.....	Richmond, Va.

Agents for the British Empire, Coats Machine Tool Co., London, England



TAPS—DIES—SCREW PLATES AND SMALL TOOLS



1 to 1000 H. P. any type—Tubular or Cellular (Spirex) — Sectional — Conventional Cast—Sheet metal, or if preferred only cases or sections.



Illustration of Allis-Chalmers Tractor.
Turbotube is used exclusively on Allis-Chalmers Tractors.

Deere & Company have found Turbotube most efficient as a cooling unit for Deere Tractors.



Durability

STRENGTH and ruggedness are built right in Turbotube without creating excessive weight. Due to the character of heavy duty machines with which Turbotube is assembled, this is a dominant advantage.

In addition higher-cooling capacity and free, unrestricted water circulation give Turbotube outstanding features that make it preferred by producers of finely engineered machines.

Turbotube should be adopted as standard equipment for your product for its efficiency.

Modine Manufacturing Co.
RACINE, WIS.

MODINE RADIATORS

The Stewart engineering department where specialists design customers' dies and adapt customers' products to the Stewart process of die casting



Die design determines casting costs

THE Stewart engineers are specialists devoted to the design and development of dies and die casting by the Stewart process. Much of Stewart success in die casting intricate parts is due to the experience and ingenuity of the engineering staff of the Stewart organization.

The intimate knowledge and seasoned experience of these engineers are at the service of manufacturers. Constructive suggestions for improvement of product and its adaptation to die casting often follow consultation with prospective customers.

Die design is executed in a modern tool room equipped to manufacture dies as economically as is consistent with the best results.

Close chemical and metallurgical control of metals and processes and rigid inspection of die castings insure uniform quality even with the huge Stewart capacity for production.

The Stewart engineers and metallurgists are at the disposal of manufacturers for advice and co-operation without obligation.

THE STEWART DIE CASTING CORPORATION
(Formerly Stewart Manufacturing Corporation)
4500 FULLERTON AVENUE - - - - CHICAGO

*Direct Factory
Representatives in*

Detroit Milwaukee
Cleveland Los Angeles
San Francisco
New York City
Birmingham Pittsburgh
Indianapolis St. Louis

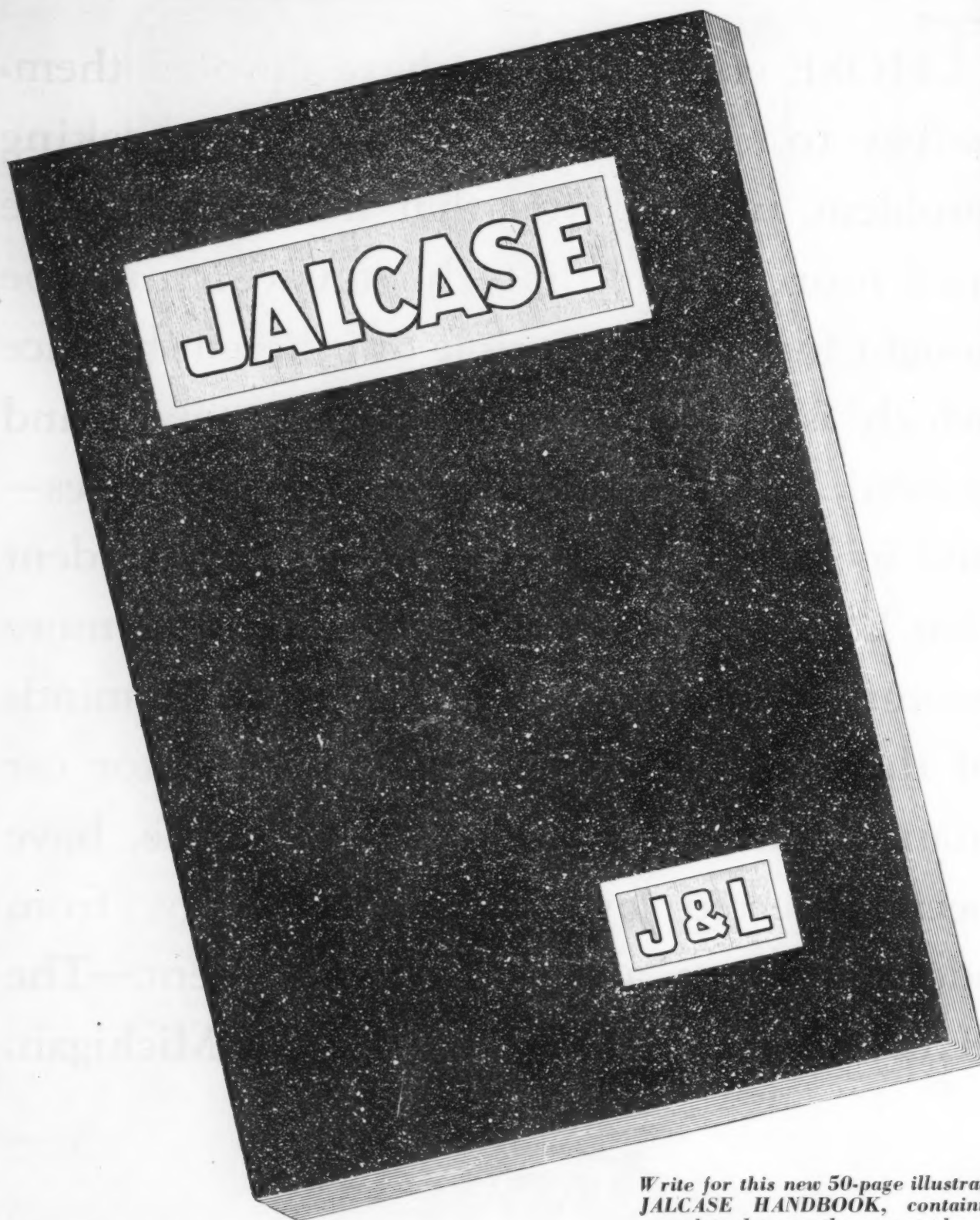
Stewart



THOSE engineers who have devoted themselves to a final solution of the braking problem, will tell you that it becomes more and more plain that the answer must be sought for in the principle of inherent balance which is found, successfully developed and proved, in Lockheed Four Wheel Brakes—and in Lockheeds alone. It is equally evident that Lockheed Hydraulics hold an even more prominent position than before in the minds of that remaining 50 per cent of motor car manufacturers who, up till this time, have been deterred by various conditions from adopting them as standard equipment.—The Hydraulic Brake Company, Detroit, Michigan.

LOCKHEED HYDRAULIC
Four **BRAKES** *Wheel*





*Write for this new 50-page illustrated
JALCASE HANDBOOK, containing
complete data on the new steel.*

JONES & LAUGHLIN STEEL CORPORATION

American Iron and Steel Works

PITTSBURGH

JALCASE

TRADE MARK

A Better Case-carburizing Steel HAVING HIGH SPEED MACHINABILITY

FIRST NOTE THE FOLLOWING PROPERTIES OF JALCASE:

Machinability—Free-cutting qualities, practically equivalent to Bessemer Screw Stock.

Case Hardening—Rate of carbon penetration is greater than in most carbon steel grades. It is superior to the carbon grades of case-carburizing steels and approaches the alloy grades.

It develops—A hard, wear resisting, normal case, free from soft spots. A tough ductile core and is recommended for case carburized parts subjected to severe abrasive wear, high stresses and repeated shocks.

Forgings—JALCASE STEEL is recommended for case-hardened forgings or forgings in which machinability is of importance.

Cold Heading—The free-cutting properties of JALCASE STEEL combined with its ability to withstand cold heading, make it a very desirable steel for cold-headed bolts, cap screws and similar work.

Then consider what JALCASE could do to your production. Here is a typical example. In making a forged gear carrier from JALCASE Steel instead of S. A. E. 1020, one manufacturer increased machining speed 34%; increased the feed 45% and thereby effected a 94% production increase. Furthermore, upon completion of 108 pieces on an automatic, the tools were in good condition, whereas previously the tools had to be reground for every 50 pieces produced.

The new JALCASE HANDBOOK, shown on the opposite page, is just off the press and may be had for the asking. It contains complete metallurgical information for users of the new steel and is fully illustrated.

JONES & LAUGHLIN STEEL CORPORATION
American Iron and Steel Works
PITTSBURGH

Exclusive Features of The H-W-Filtrator

The H-W-Filtrator is designed and built with the following requirements clearly in mind, namely:—(a) eliminating deadly abrasives, (b) keeping the body of the oil constant, which will make for quieter operation of the engine and lengthen the life of a motor.

It has exclusive features which merit the consideration of those who seek to meet the demand for perfect lubrication.

Durability (obviating the replacement of units or parts), cleanable filtering elements (without removal) and leakproof (at all oil pressures) are added reasons for incorporating the H-W-Filtrator in your construction specifications.

The preferred installation is such that there are no exposed oil lines. The filtering element is in series between the pump and motor bearings, thereby providing 100% protection against abrasives.

Our experts are at your service to assist you in your lubricating problems. Correspondence invited.

THE H-W-FILTRATOR

is manufactured under the Hall-Winslow patents by the

Sheet Steel Products Company,

Michigan City, Ind.

Sold by

Rich Tool Company

Valve specialists in silchrome and other alloy steels

1501 E. Ferry Ave.

Detroit, Mich.

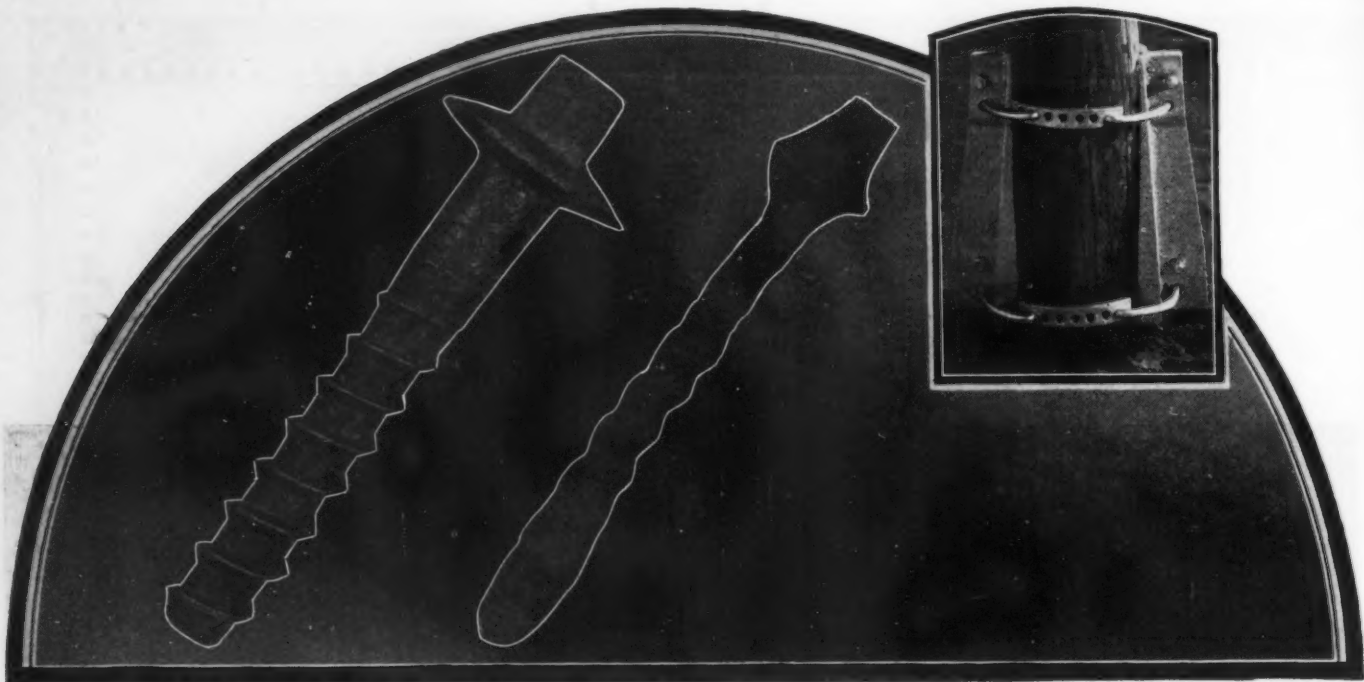
**Marmon in 1906****Marmon in 1926**

Prest-O-Lite still serving Marmon

THE Marmon of 1906 was a great automobile + the Marmon of 1926 is a great automobile + twenty years have brought many changes — but Marmon's belief in Prest-O-Lite has not changed + the steady advance of Marmon has been most noteworthy + today, it stands high in the company of truly fine motor-cars + and Prest-O-Lite's satisfaction in having been able to meet the ever exacting requirements of Marmon is not slight + Prest-O-Lite is proud of the long association, and + so is Marmon.

Prest-O-Lite

PREST-O-LITE STORAGE BATTERIES FOR MOTOR-CARS AND RADIO



A striking illustration of the rust resisting properties of Certified Malleable. Two screw spiles that were put in service at the same time. The one on the left is Certified Malleable.

Pole reinforcement of Certified Malleable Iron. Rust resistance combined with great strength is essential in this device.

Certificate Holders During Quarter Ending Sept. 30th, 1926

Albany Malleable Iron Co.	Voorheesville, N. Y.
Albion Malleable Iron Co.	Albion, Mich.
American Chain Co.	Bridgeport, Conn.
American Malleable Castings Co.	Marion, O.
Badger Malleable & Mfg. Co.	Lancaster, N. Y., and Oconomowoc, Mich.
Baltimore Malleable Iron & Steel Casting Co.	Baltimore, Md.
Bell City Malleable Iron Co.	Racine, Wis.
Chain Belt Co.	Milwaukee, Wis.
Chicago Malleable Castings Co.	West Pullman, Chicago, Ill.
Columbia Malleable Castings Co.	Columbia, Pa.
Columbus Malleable Iron Co., The	Columbus, O.
Danville Malleable Iron Co.	Danville, Ill.
Dayton Malleable Iron Co., The	Dayton, O., and Dayton, Ill.
Decatur Malleable Iron Co.	Decatur, Ill.
Devlin Mfg. Co., Thomas	Philadelphia, Pa.
Eastern Malleable Iron Co., The	Newark, N. J.
Works, Newburgh, Conn.	Bridgeport Malleable Iron Works, Bridgeport, Conn.
Troy Malleable Iron Works, Troy, N. Y.	Wilmington Malleable Iron Works, Wilmington, Del.
Vulcan Iron Works, New Britain, Conn.	Erie Malleable Iron Co., Erie, Pa.
Federal Malleable Co.	West Allis, Wis.
Fort Pitt Malleable Iron Co.	Pittsburgh, Pa.
Fraser & Jones Co.	Syracuse, N. Y.
General Electric Co.	Erie, Pa.
Glancy Malleable Corporation	Waukegan, Wis.
Illinois Malleable Iron Co.	Chicago, Ill.
Iowa Malleable Iron Co.	Fairfield, Ia.
Kalamazoo Malleable Iron Co.	Kalamazoo, Mich.
Lacmin Car Co.	Lacmin, N. H.
Lakeland Malleable Castings Co.	Racine, Wis.
Link-Belt Co.	Indianapolis, Ind.
Marion Malleable Iron Works	Marion, Ind.
Moline Malleable Iron Co.	St. Charles, Ill.
National Malleable & Steel Castings Co.	St. Louis, Mo.
Cleveland, O., Chicago, Ill., Indianapolis, Ind., Toledo, O., E. St. Louis, Ill.	Northern Malleable Iron Co., St. Paul, Minn.
Northwestern Malleable Iron Co.	Milwaukee, Wis.
Pacific Malleable Castings Co.	Portland, Ore.
Pittsburgh Malleable Iron Co.	Pittsburgh, Pa.
Shelby Island Malleable Iron Works	Hillsgrove, N. J.
Rockford Malleable Iron Works	Rockford, Ill.
Ron-Mechan Foundry, The	Chattanooga, Tenn.
St. Louis Malleable Casting Co.	St. Louis, Mo.
Superior Products Co.	Superior, Mich.
Standard Malleable Castings Co.	Terre Haute, Ind.
Stewart Co., The	South Milwaukee, Wis.
Superior Steel Castings Co.	Boston Harbor, Mich.
Syracuse Co., The	Rochester, N. Y.
Temple Malleable Iron & Steel Co.	Temple, Pa.
Terre Haute Malleable & Mfg. Co.	Terre Haute, Ind.
Truett Malleable Iron Co., The	Truett, N. J.
Union Malleable Iron Co., The	E. Moline, Ill.
Vermilion Malleable Iron Co.	Hopkinton, Ill.
Wagner Malleable Castings Co.	Hammont, Ind., and Beloit, Wis.
Warren Tool & Forge Co.	Warren, O.
Webster Mfg. Co., The	Chicago, Ill.
Windsor Malleable Iron Co.	Milwaukee, Wis.
York Mfg. Co.	York, Pa.
Zaner's Malleable Co.	Zaner's, O.

Rust Resistance

Rain, snow, mud and other corroding agents take a daily toll from vital parts of farm implements, automotive and general industrial machinery. Wherever Certified Malleables are used they will cut down repairs and maintenance costs due to these factors.

Because it is essentially one of the purest forms of iron, due to the method of "heat treating" or annealing, Certified Malleable is more resistant to rust than other forms of iron and steel.

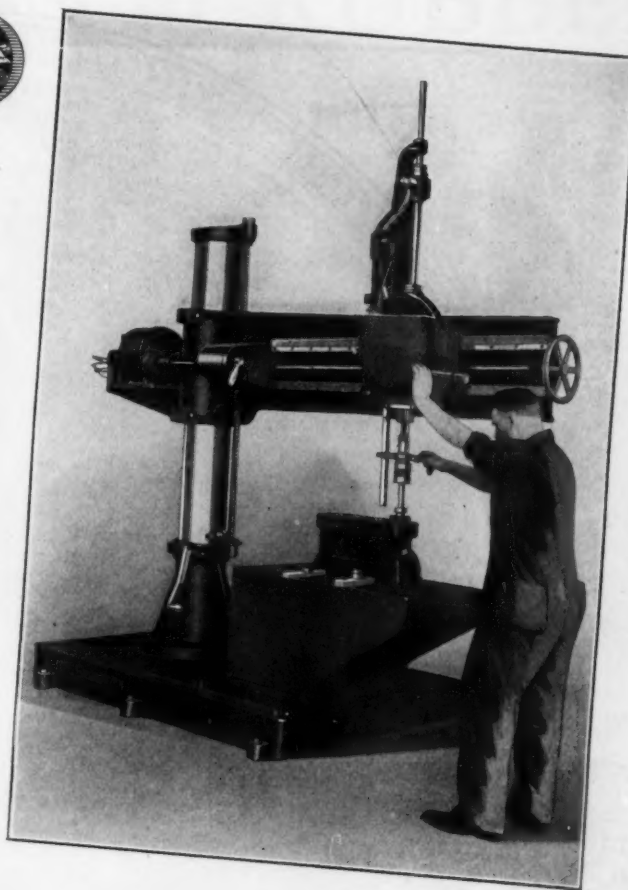
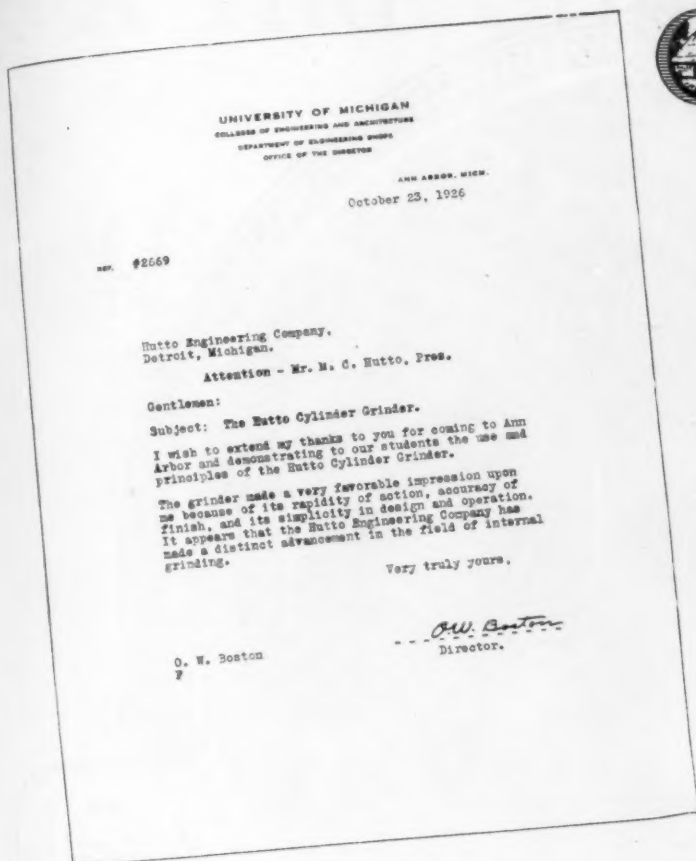
This superior material therefore offers a combination of valuable physical properties not found in any other single product. It combines rust resistance, great strength and light weight, ease and economy in machining, toughness, ductility, and resistance to shock and abuse.

Certified Malleables are uniform in structure and other physical properties. They regularly exceed 50,000 lbs. tensile strength, 10% elongation and 30,000 lbs. yield point.

AMERICAN MALLEABLE CASTINGS ASSOCIATION
UNION TRUST BUILDING CLEVELAND, OHIO



CERTIFIED MALLEABLE CASTINGS



HUTTO CYLINDER GRINDERS

"A DISTINCT ADVANCEMENT IN INTERNAL GRINDING"



Picture on left illustrates the HUTTO Radial Grinder—a new development in the field of internal grinding—rapid, accurate—an ideal tool for production or service work.

Model KKS Brake-type production grinder used in single or multi-spindle Hutto Grinding Machines.

Because of its rapidity of action, accuracy of finish and simplicity of design, the HUTTO Cylinder Grinder is a distinct advancement in the field of cylinder bore grinding.

The HUTTO Cylinder Grinder is positive set, self aligning, self-centering and unchanging, holding bores straight, round, grinding bores to a satin finish and to a tolerance limit of one-half thousandth.

HUTTO Grinders are used by 85% of automobile manufacturers for production work—and the portable service grinder is the ideal reconditioning tool for the service station.

Give your customers HUTTO results before they demand it.

WRITE FOR
"PROFIT FROM THE DAILY GRIND"

HUTTO ENGINEERING COMPANY

515 Lyncaste Ave.

Detroit, Mich.

OVER 20,000 SATISFIED USERS



METAL stampings are so important in automobile manufacture that designing engineers first consider whether the part under consideration can be stamped out of pressed steel before passing to the consideration of another material. (Many malleables and castings have been replaced by pressed steel in body construction; the transition is still progressing. (Our staff will gladly confer with yours on problems of this kind.

Mullins Body Corporation, Salem, Ohio Detroit Office: 5-139 General Motors Bldg.

MULLINS



A TIRE CHAIN of RUBBER

Long-Wearing—Quiet

GOODYEAR Rubber Tire Chains overcome the two chief objections to ordinary chains. They are *quiet*, and they *wear long*.

They are saving of tires. Under all conditions of road and load they offer car control and safety. Here is the whole story of the Goodyear Rubber Tire Chain:

Quietness: There's no clanging on the pavement or banging on the fenders with Goodyear Chains. Rubber cross links take the place of steel.

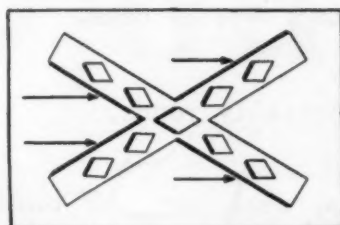
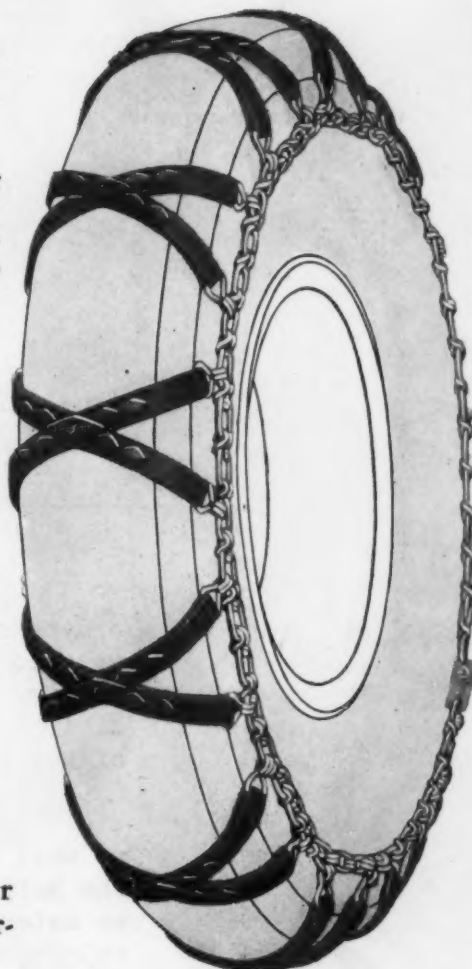
Long Wear: Mile for mile, one set of Goodyear Chains will, in most cases, outwear several sets of ordinary tire chains.

Tire-Saving: The broad rubber cross links guard against cutting or bruising of the tire tread, and especially in deep ruts give valuable protection to tire sidewalls.

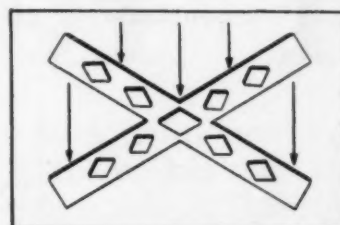
Ease of Application: Goodyear Chains are easy to apply. You put them on and leave them on—over mud, wet and dry pavements, or snow.

Security: Goodyear Chains employ the non-skid principle of the famous Goodyear All-Weather Tread magnified for maximum gripping action. Scientifically designed to resist skidding in any direction.

Convince yourself of these facts by having your car equipped with Goodyear Rubber Tire Chains at the nearest Goodyear Service Station.



Angularity of cross links sets up effective resistance to skidding sidewise



Squeegee action of rubber cross links holds the car firmly on wet pavement

Made by the makers of Goodyear Tires

GOOD YEAR

TIRE CHAINS

Copyright 1926, by The Goodyear Tire & Rubber Co., Inc.

THE MOTOMETER COMPANY, INC.
LONG ISLAND CITY, N. Y.

OFFICE OF THE PRESIDENT

To the Automotive Industry.

Gentlemen:-

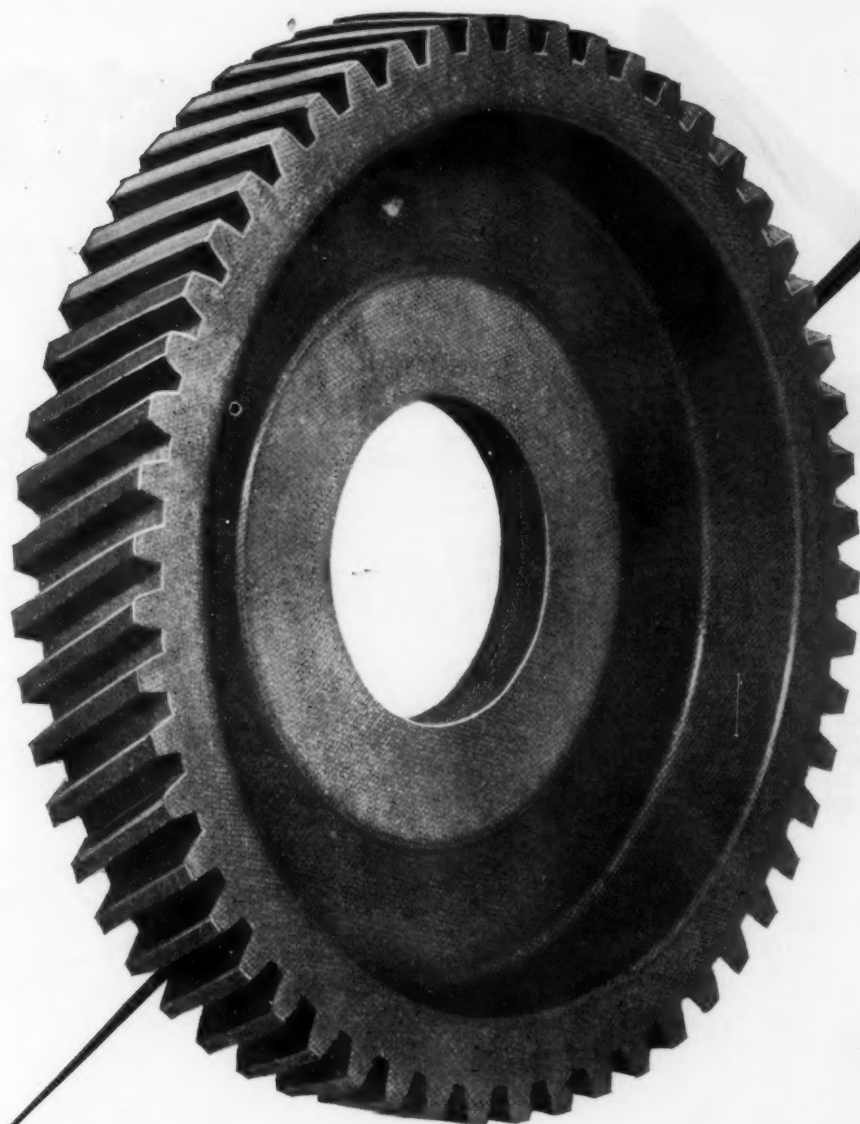
As we pass another milestone and near the close of a most prosperous year to our industry, we feel it is but fitting for us to state our genuine appreciation of old associates and the value of new friends.

In the name of this Company, as well as our newly acquired division The National Gauge and Equipment Company, we extend to you the wish that you may enjoy continued success, and that the confidence we have enjoyed in the past may continue to grow during the years to come.

Cordially yours,

Geo. H. Townsend

December 23rd, 1926.



8 out of 10



If Textolite replacement gears are desired, complete details and the name of the nearest distributor may be obtained from:

John C. Hoof & Company
157 West Illinois St., Chicago, Ill.

8 out of 10 of all new cars, using non-metal gears in their timing mechanism, built in 1925, were equipped with a Textolite Silent Timing Gear.

The percentage for 1926 will be even greater.

The trend in the design of timing mechanisms is towards G-E Textolite Silent Timing Gears.

Every automobile executive and engineer should know the full details of these exceptional timing gears.

GENERAL ELECTRIC

GENERAL ELECTRIC COMPANY, SCHENECTADY, N. Y., SALES OFFICES IN ALL PRINCIPAL CITIES

830-5

4 Reasons

Quality Products

Long Mileage

Silent Operation

Immense Manufacturing Facilities

Morse Honor Roll

Cadillac Eight
Chandler Six
Chrysler Six (60)
Chrysler Six (70)
Chrysler Six (80)
Cleveland Six (31)
Cleveland Six (43)
Davis Six (92)
Davis Six (93)
Diana Eight
Essex Six
Fiat Six—(5-90)
Flint Six (Jr.)
Flint Six (60)
Flint Six (80)
Hudson Six
Hupmobile Six
Hupmobile Eight
Jordan Eight (GL)
Jordan Eight (L)
Lincoln Eight
Moon Six (A)
Oakland Six
Oldsmobile Six
* } A manufacturer of high
grade Sixes and Eights
* } —name on request
Peerless Six (72)
Peerless Six (80)
Pontiac Six
Rickenbacker Six
Rickenbacker Eight
Star Four
Star Six
Stearns K Four (B)
Stearns K Six (75)
Stearns K Six (95)
Continental Motors

Used in a number of the
cars listed

Engine Models W-5

6-E	7-U	7-Z
8-S	8-U	9-K
9-L	11-U	12-Z
14-L	14-U	20-L

This list contains no duplications or obsolete models

THESE four factors are responsible for the steady increase in the use of Morse Silent Chains until today practically every worth while motor car using chain front end drive is equipped with a Morse Chain.

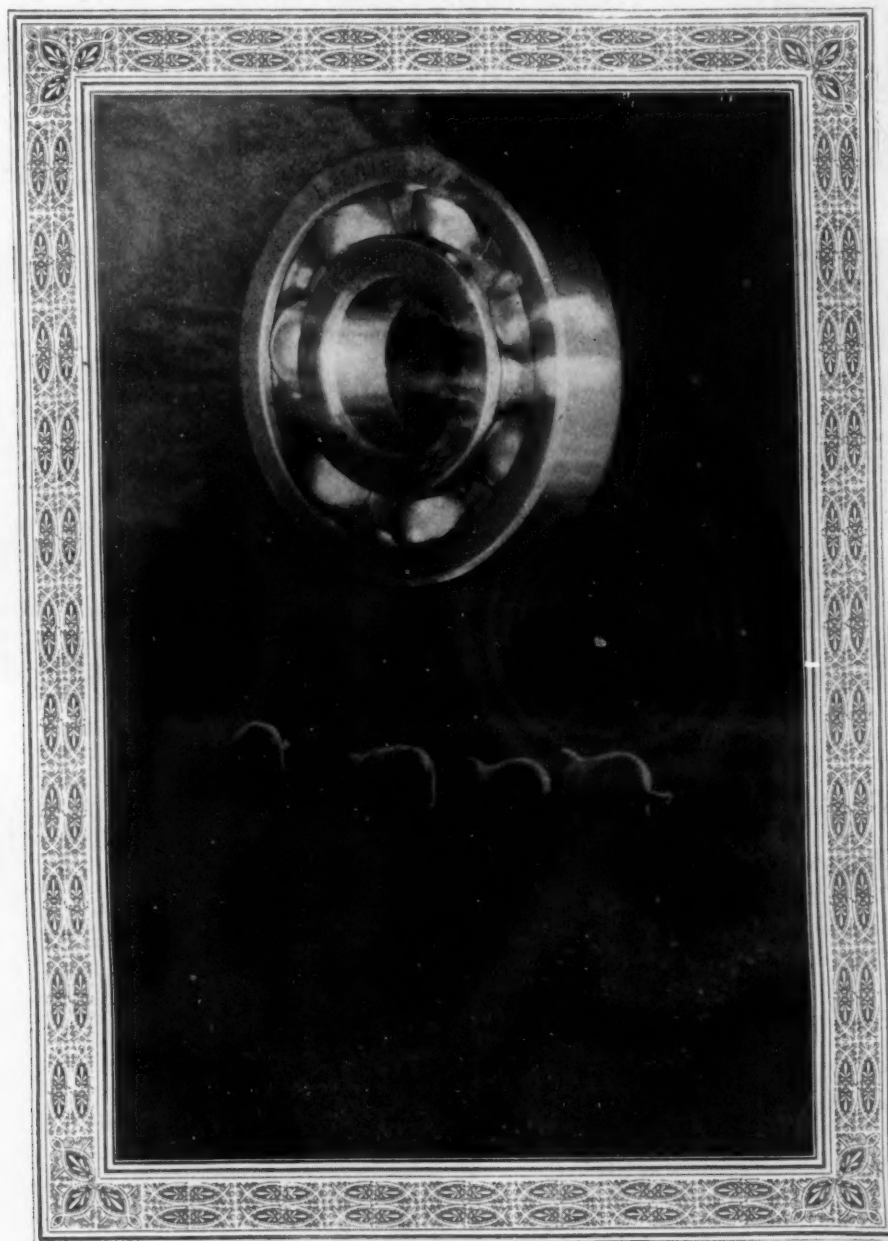
MORSE CHAIN COMPANY

Main Office and Works
ITHACA, NEW YORK

Sales and Engineering Office
DETROIT, MICHIGAN

MORSE

GENUINE SILENT CHAINS



Every Fafnir Ball Bearing is made as though the whole reputation of the Fafnir Bearing Company depended on its individual excellence.

The Fafnir Bearing Company, New Britain, Conn., Newark, Chicago, Cleveland, Detroit





The Ever-Increasing Popularity of Republic Busses is Due to Serviceability

IN no other field is this element of serviceability more closely measured than in that of public conveyances. Even where the continuance of a franchise is not influenced by the operator's ability to maintain schedules, public patronage is enhanced by close adherence to the factor of time.

Measured by all the standards of operators and patrons, it is plain to see why Republic Busses are enjoying a steadily increasing popularity.

Their comfort, their ability to operate regularly and their ample power—provided by Lycoming Engines—are assurance of reliable performance and easily maintained schedules, day in, day out.

All Republic Busses, Models 80 and 81, are Lycoming powered.

LYCOMING MANUFACTURING COMPANY

Makers of Fine Fours, Sixes and Eights-in-Line
WILLIAMSPORT, PENNSYLVANIA

Export Department—44 Whitehall Street, New York City
MEMBER OF MOTOR TRUCK INDUSTRIES, INC., OF AMERICA



LYCOMING

Motors



Years Ahead in Automobile Motor Efficiency

Tested— by millions of users every day

FOR years the Auto-Lite system has been subjected to millions of practical service tests every day—by its users. (The manner in which Auto-Lite has stood up under these tests accounts for its universal recognition—its general acceptance as the standard in

starting, lighting and ignition equipment. (Such equipment is a worthy associate of the best features that can be built into the car you sell. Auto-Lite, in its field, is a wholly dependable guardian of your name.

THE ELECTRIC AUTO-LITE COMPANY

Office and Works: Toledo, Ohio

Also Makers of DÉJON



Auto-Lite

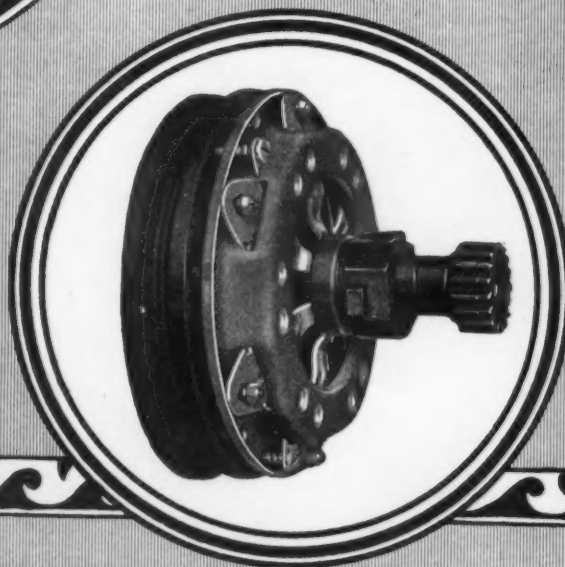
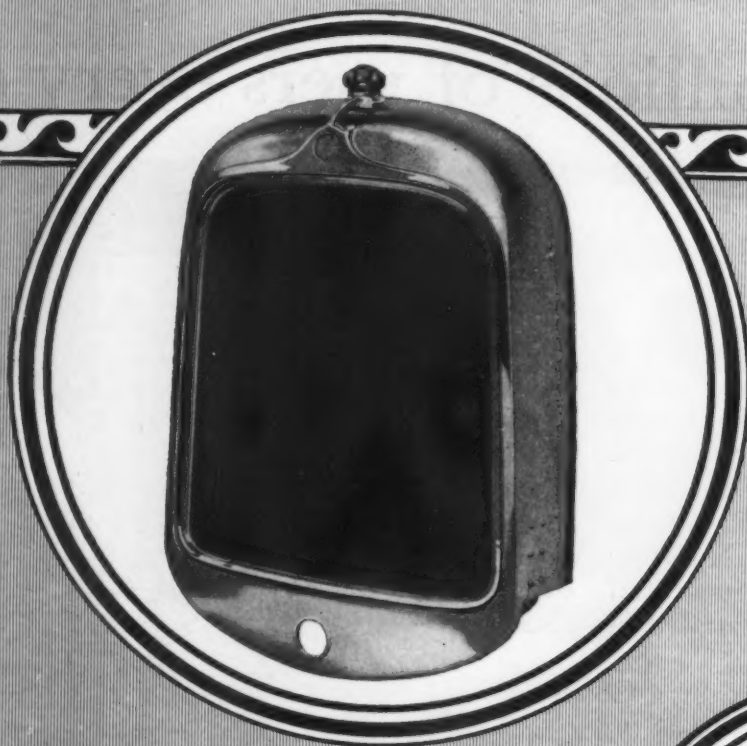
Starting, Lighting & Ignition



American Enamel Magnet Wire Plant,
Muskegon, Mich.

Burt Foundry, Toledo, Ohio

Electric Auto-Lite Foundry,
Fostoria, Ohio



Clutches and Radiators of HONEST
VALUE, that continue to hold the respect
of the Automotive Industry.

LONG MANUFACTURING CO., Detroit, Mich.

LONG

TIRE ECONOMY • ACCESSIBILITY • APPEARANCE



Walter uses DAYTONS

WALTER SNOW FIGHTERS are used for clearing snow and ice from city streets and highways in Northern United States and Canada.

Terrific power and traction is needed to clear away snow and ice without stalling or side-slipping.

Walter uses Dayton Steel Wheels built for four wheel drive. They help the truck to develop its maximum speed and traction.

Nearly all leading truck makers use Dayton Steel Wheels. Specify them.

Far Western Distributor

The Kay-Brunner Steel Casting Co., of Los Angeles, is the exclusive manufacturer and distributor of Dayton Steel Wheels, west of the Rockies.

Deliveries are timely and steady

THE DAYTON STEEL FOUNDRY COMPANY, Dayton, Ohio

Dayton

The Mark of a Good Wheel

STRENGTH • LIGHT WEIGHT • DURABILITY

Square dealing built Linde's reputation

IN THE emergencies of the last fifteen years—and there have been emergencies of many kinds—the spirit of a business house has had many opportunities to show itself.

Were the customers' rights protected? Or were excuses delivered instead of materials, and customers left to look out for themselves?

Linde's reputation with its customers during all these years is one of which the company is justly proud. The rights of the customer have always been paramount.

As a Linde customer you are sure of your oxygen supply, not only in times of plenty, but in times of emergency as well. It is guaranteed by 37 Linde plants, 105 Linde warehouses and by the Linde principle of giving the customer a square deal.

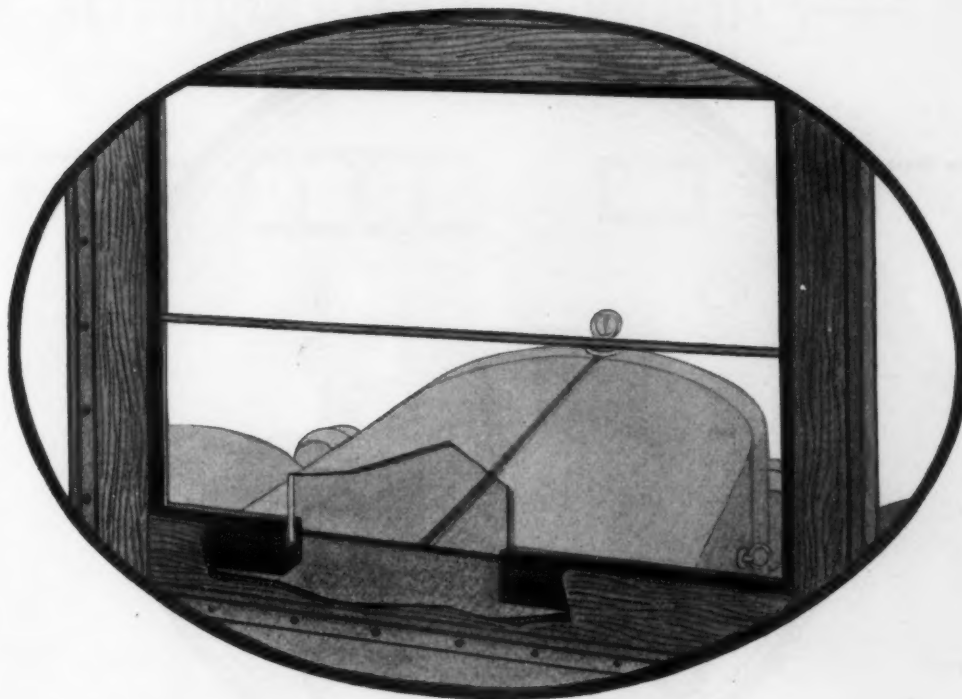
THE LINDE AIR PRODUCTS COMPANY

*Manufacturers of oxygen, nitrogen, pyrogen, argon and neon
Producers of helium for scientific purposes*

General Offices: Carbide and Carbon Building
30 East 42d Street, New York
37 Plants—105 Warehouses



OXWELDED PIPE FITTINGS are extremely successful and their flexibility recommends them to the average plant man. The Linde Procedure Control on oxwelded pipe fittings gives detailed instructions and is especially valuable on obscure points which enter vitally into the ultimate success of the operation.



But if your windshield tubing is from Dahlstrom—

It is rigid and substantial. Being process welded along the seam, water cannot seep in and start rusting from the inside of the tubing.

For years motor car makers have been using Dahlstrom for mouldings and shapes. Their cars look better—sell faster. They keep coming back. What is your problem? Let us help.

DAHLSTROM METALLIC DOOR COMPANY

INCORPORATED 1904

Jamestown, N. Y.

Representatives in principal cities.

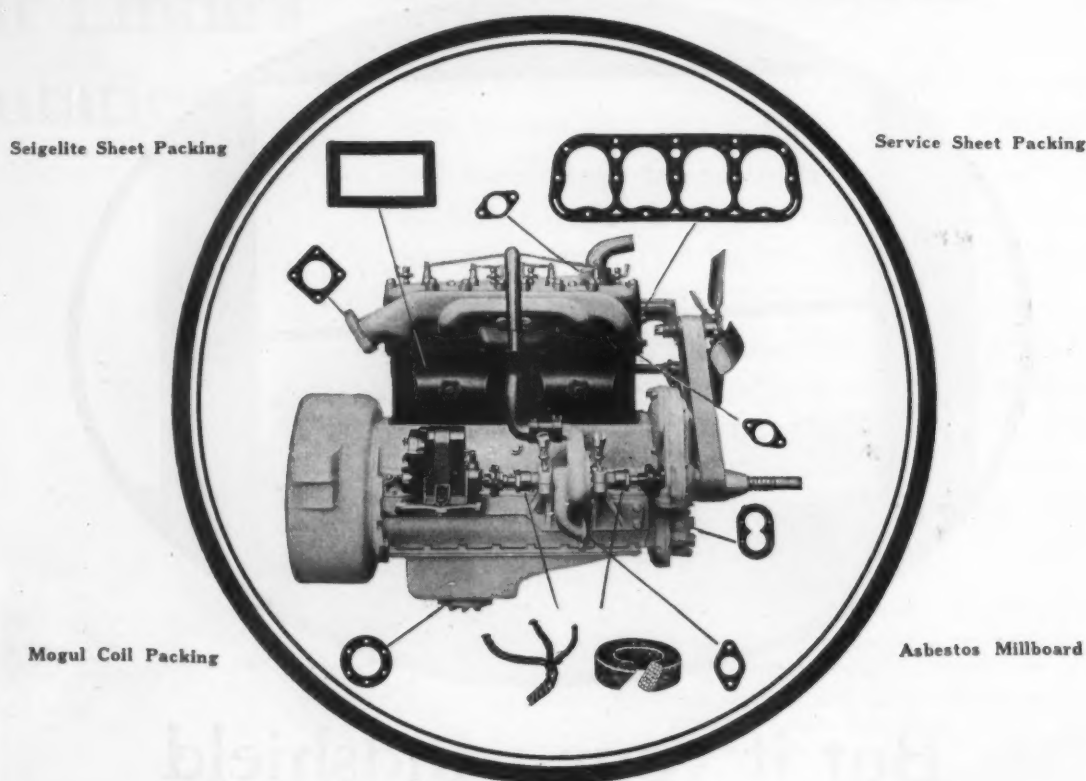
Glass Channels
Cushion Retainers
Door Caps
Finishing Mouldings
Floor Mouldings
Garnish Mouldings
Instrument Panels
Windshield Tubing,
Etc.
Wainscot Panels

DAHLSTROM

Metal Shapes & Mouldings

BRANCH OFFICES
NEW YORK—
475 Fifth Avenue
CHICAGO—
19 So. La Salle St.
DETROIT—
5-251 General
Motors Bldg.
PHILADELPHIA—
514 Bulletin Bldg.
CLEVELAND—
684 The Arcade

Packings, Older Than The Automobile



LONG before the advent of the internal combustion engine, Johns-Manville Mogul Coil Packing was used extensively on pumps and engines; Johns-Manville Seigelite was used on pipes containing various kinds of active liquids; Johns-Manville Service Sheet was used where reasonably high temperatures prevailed; and Johns-Manville Asbestos Millboard was used where very high temperatures were encountered.

Our past experience in manufacturing packings for every conceivable condition and our extensive manufacturing facilities enable us to place at your disposal packings that will successfully meet the extremely severe conditions of the Automotive Industry.

JOHNS-MANVILLE, Inc.
292 Madison Ave., at 41st St., N. Y. C.
Branches in 64 Large Cities
For Canada: Canadian Johns-Manville, Inc., Ltd.
Toronto

JOHNS-MANVILLE

Automotive Equipment

BETHLEHEM

Rolled Steel Truck Wheels

for strength and resiliency—

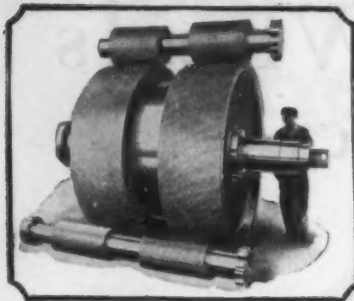


BETHLEHEM STEEL COMPANY, General Offices: BETHLEHEM, PA.

District Offices in New York, Boston, Philadelphia, Baltimore, Washington, Atlanta, Pittsburgh, Buffalo
Cleveland, Detroit, Chicago, Cincinnati, St. Louis, Seattle, San Francisco, Los Angeles, Portland

BETHLEHEM

Pinions of Alloy Steel Transmit Her 6,000 Horsepower

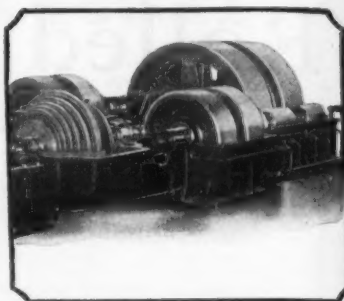


Double helical reduction gear unit to be installed in the famous S. S. "Malolo" now under construction. The 4 De Laval reduction gears for the "Malolo" are the largest of any yet built in the U.S.A.—the pitch diameter being 140" and the total width of working face, 57". Pinion gears are made of NICKEL STEEL.

TO assure the economical and dependable performance of marine transmissions, designers specify Alloy Steel for speed reduction pinions.

They know that only Alloy Steel, with its exceptional wearing qualities—its high fatigue resistance—its toughness and strength—will withstand the shocks and vibrations incident to transmitting the tremendous power from high speed turbine shafts to slow speed propeller shafts through a gear reduction of 35 to 1.

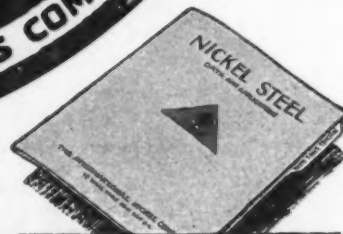
Why not let our engineers suggest where you should use Alloy Steel in the manufacture of YOUR product?



6,000 H. P. De Laval compound turbine and double helical reduction gear units in the S. S. "El Oceano", fast freighter of the Southern Pacific Line. Pinion gears in reduction units made of NICKEL STEEL.



**ALLOY
STEEL**



This folder for permanently filing Nickel Steel data will be sent free on request. Write for it today, mentioning this periodical.



THE INTERNATIONAL NICKEL COMPANY, 67 WALL STREET, NEW YORK CITY
Producers of INCO Nickel in all commercial forms





Don't lose *your* head when buying your coal!

IN these very strenuous times many lose their heads. Experienced buyers have found that it pays to purchase coal from a large and dependable source of supply which takes care of its obligations under all conditions.

The great resources of The North American Coal Corporation and its extensive shipping facilities will prove a source of permanent satisfaction to you.

Pittsburgh Terminal Youghiogheny Gas
Pittsburgh Steam Powhatan
Atwater Pocahontas Pittsburgh No. 8

Logan County, W. Va. and E. Kentucky Gas,
By-Product, Steam and Domestic coals
Pittsburgh Terminal Special Coal for Water
Gas Generator Use

FIFTEEN MILLION TONS ANNUALLY

Wabash Bldg.
Pittsburgh, Pa.

Prudential
Bldg.
Buffalo, N. Y.

2nd Nat. Bank
Bldg.
Akron, O.

**THE NORTH AMERICAN
COAL CORPORATION**

UNION TRUST BLDG. CLEVELAND, OHIO

THE INLAND COAL & DOCK CO. CANADA COAL LTD. THE UNITED COAL & DOCK CO.

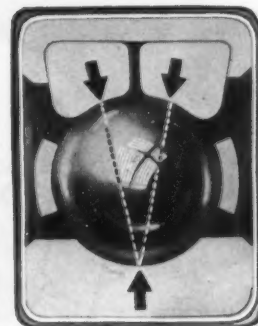
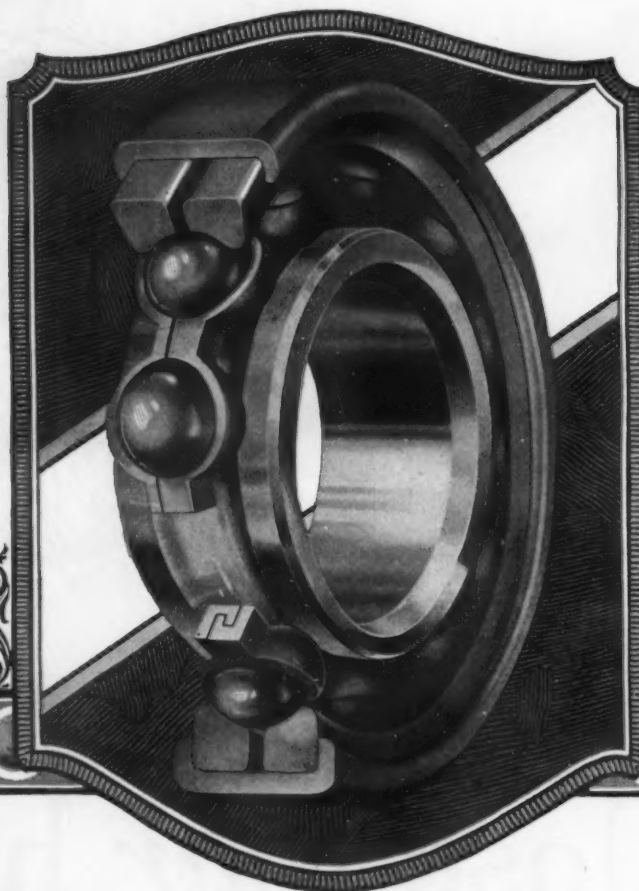
2nd Nat. Bank
Bldg.
Toledo, O.

Canada Coal
Ltd., Toronto,
Canada

No. 1 Broadway
New York City



*The Mark of
Quality*



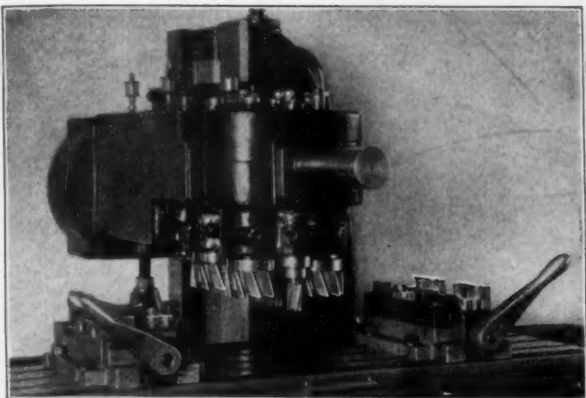
*The famous
3-area
contact*

A Notable Achievement in Bearing Design

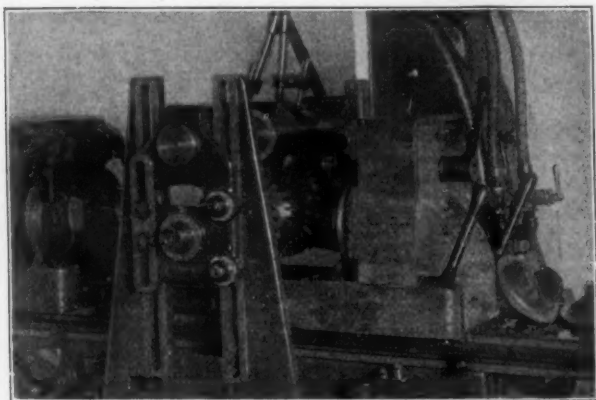
The 3-area contact is the outstanding feature of Schatz "Universal" Annular Ball Bearings. This notable achievement in design gives to "Universal" unusual adaptability. Sudden and heavy radial thrusts in no way reduce efficiency. Schatz "Universal" bearings are preferred because they give longer and better bearing service under any and all conditions.

THE FEDERAL
BEARINGS COMPANY, INC.
Poughkeepsie New York

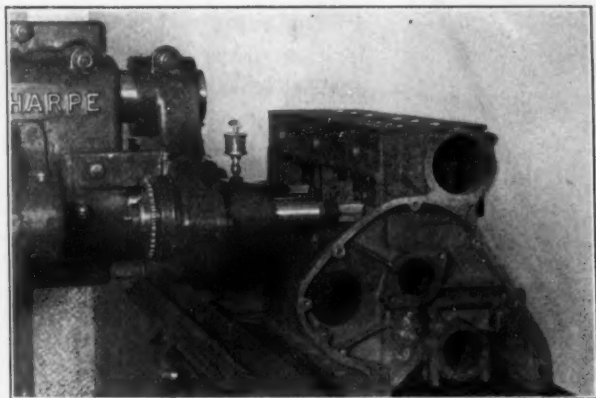
Schatz
"UNIVERSAL"
Registered *Annular* U.S. Pat. Off.
BALL BEARING



Milling three surfaces simultaneously on bearing caps is readily accomplished with this eight spindle attachment. Each fixture holds four caps and the entire set up is conducive to convenient operation and economical production



The milling of tough steel forgings for universal joints is readily accomplished on a standard No. 33 Automatic. Especially designed work fixtures, each holding two pieces, are used



Milling the tappet bracket bosses on this heavy cylindrical block is easily accomplished by a two spindle attachment bolted to the spindle head

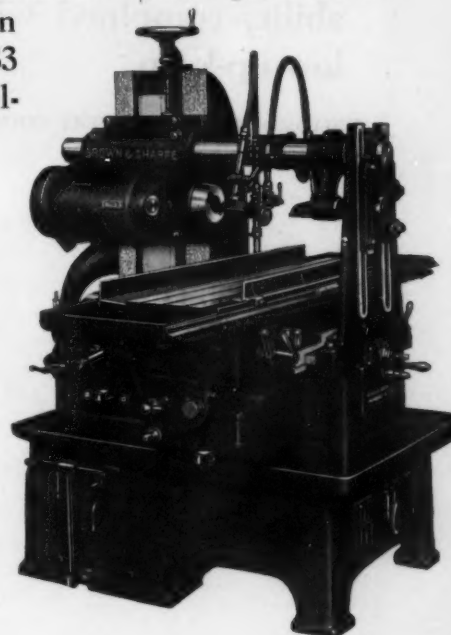
Base your production estimates on the performance of Brown & Sharpe Automatic Milling Machines

A LARGE quantity of work now done with ordinary milling equipment could be produced much more profitably with Brown & Sharpe Automatics.

Three production jobs are shown on automotive parts. In each case the manufacturer compared his previous production with the production possible with Brown & Sharpe Automatics, and decided to save money by using the Automatics.

Every machine shown in these pictures is a standard Brown & Sharpe No. 33 Automatic Milling Machine.

Special fixtures, and in two cases, special attachments are used which are readily detachable.



Call in our representative and go over your needs with him—also send for the booklet, "Automatic Milling Machines," which describes all three sizes.

BROWN & SHARPE

BROWN & SHARPE MFG. CO.



PROVIDENCE, R. I., U. S. A.

MANUFACTURERS of MODERN MACHINE TOOLS, CUTTERS and SMALL TOOLS

Advertisements like this continue to tell car-owners the story of Willard Quality and Willard Service—a story of battery dependability combined with low up-keep.

WILLARD STORAGE BATTERY COMPANY
Cleveland, Ohio
U. S. A.



Rubber cases used in Willard Batteries are tested with a current of 18,000 volts. Only perfect cases and cells can pass, for this test burns holes right through imperfect ones.

that's
Quality



In the same way that Willard quality protects you against leaky cases and cells, our standards of battery inspection insure your receiving full measure of useful battery life in your car.

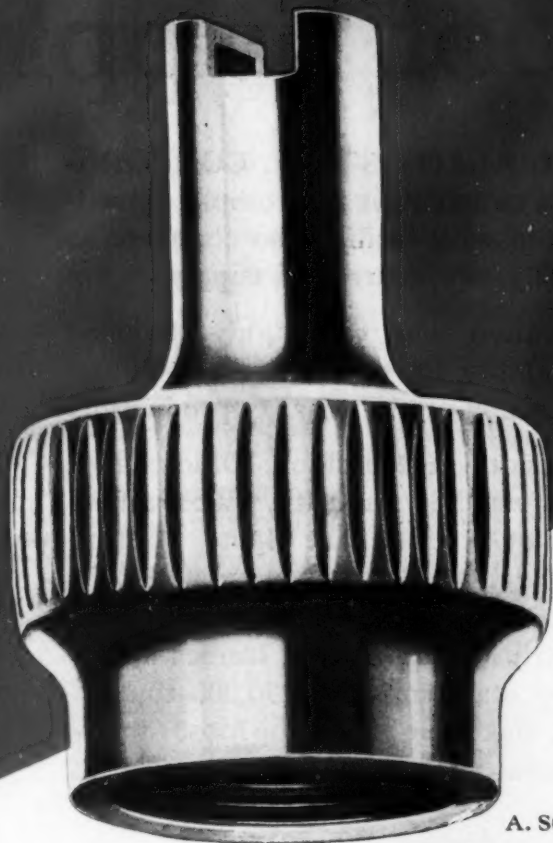
that's
Service

The
Willard Battery
men

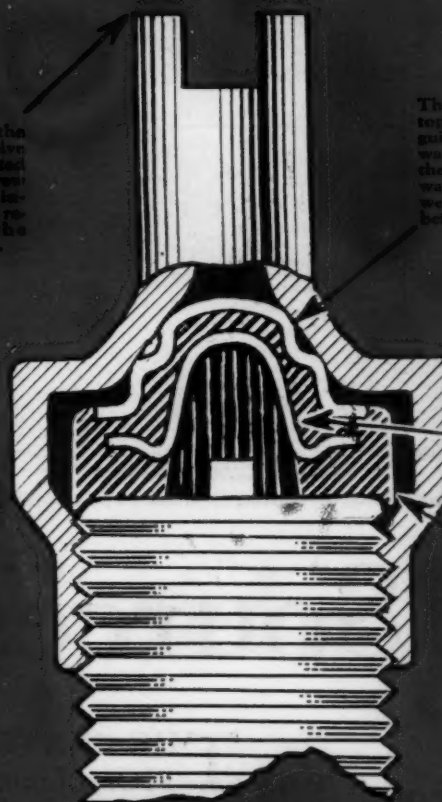
We Service All Makes
and Sell Willards for
All Cars—for Radio, too.

GUARANTEED

to seal air
at the
mouth
of Tire
Valve



The top of the Schrader Valve Cap is slotted to act as a screw driver in inserting and removing the valve inside.



The metal pivot plate on the top of the washer acts as a guide for centering the washer over the mouth of the valve and prevents the washer from distorting and wearing when the cap is being screwed on or off.

The dome-shaped inner plate prevents the side walls of the rubber washer from collapsing when sealing the mouth of the valve and keeps a permanent recess for the top of the valve pin.

The metal reinforced rubber washer inside the cap makes perfect air-tight seal over the mouth of the valve when the threaded cap body is screwed down tight by hand.

THE improved Schrader No. 880 Valve Cap is guaranteed airtight up to 250 lbs., when screwed down tight by hand.

Should the valve inside become worn out or damaged, the Schrader No. 880 Valve Cap prevents escape of air at mouth of the valve until the inside can be replaced.

The metal reinforced dome-shaped rubber washer shown in the diagram above is an exclusive Schrader feature.

The Schrader No. 880 Valve Cap is an important part of the Schrader Tire Valve. For maximum efficiency, be sure that every tire valve is equipped with a Schrader No. 880 Valve Cap.

A. SCHRADER'S SON, Inc., BROOKLYN, Chicago, Toronto, London

Schrader

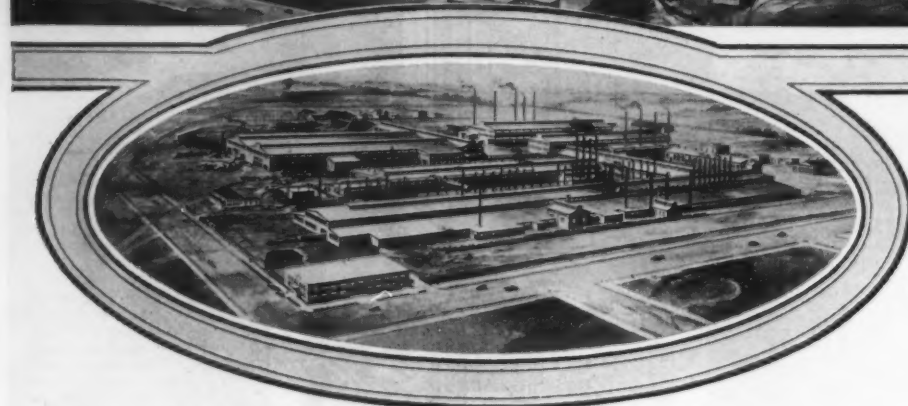
Makers of Pneumatic Valves Since 1844

Tire Valves

Tire Gauges



Main Plant of United Division,
Canton, Ohio



South Plant of United Division, Canton, Ohio

Now Two Sources of Supply

Agathon Alloy Steels

In Daily Production

Nickel, Chrome-Nickel
UMA, Molybdenum
Chrome-Molybdenum
Nickel-Molybdenum
Vanadium, Chrome
Vanadium, Chrom-
ium, etc.

Deliveries in Blooms,
Billets, Slabs, Hot
Rolled, Heat Treated,
and Cold Drawn Bars.

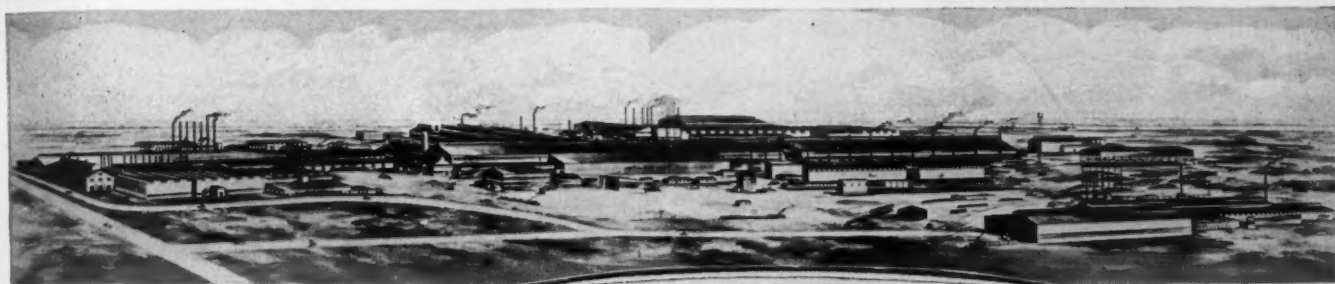
THE CENTRAL ALLOY STEEL CORPORATION combines two distinct and completely self-contained steel plants with facilities so complete as to constitute virtually two sources of supply.

No other organization is so thoroughly equipped with metallurgical ability for scientific research and for the actual supervision of high quality production.

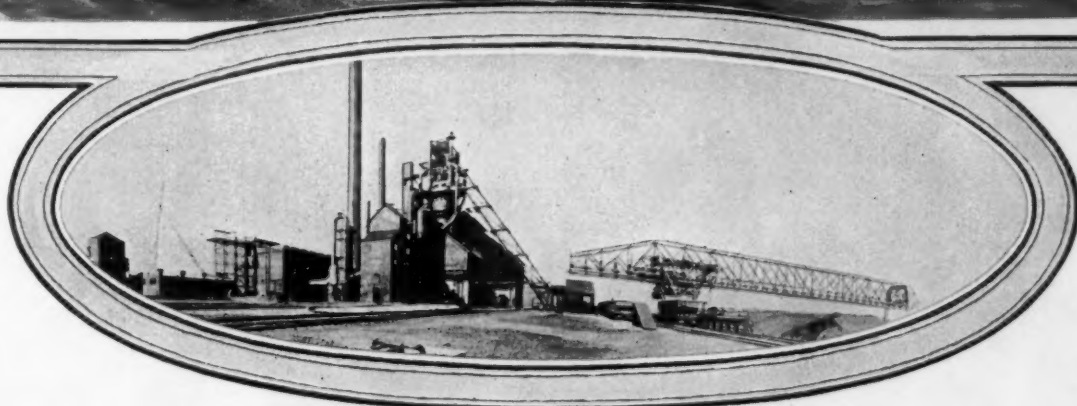
The Central Division, at Massillon, Ohio, has a blast furnace of 800 tons daily capacity, which will be served by a 49-oven by-product coke plant. Melting and rolling capacity for a yearly production of 400,000 tons of alloy steel blooms, billets, bars, etc., 100,000 tons of hot-rolled strip for automobile frames, brake drums and all heavy stampings, and 70,000 tons of special finish sheets, make this one of the most important units in the special steel industry.



AGATHON



Main Plant of
Central Division,
Massillon, Ohio



Blast Furnace, Central Division, Massillon, Ohio

from Ore to Finished Steel

The United Division, at Canton, Ohio, has a blast furnace of 650 tons daily capacity served by a 47-oven by-product coke plant. The capacity for alloy, carbon and special steel blooms, billets, bars, etc., is 520,000 tons per year. Electric furnace equipment provides 50,000 tons of electric steels annually, while the capacity in both common and special finish sheets, black, galvanized, terne-coated, etc., is 280,000 tons per year.

The combined facilities of this great organization make possible to a greater degree than ever before a highly efficient and well-rounded service to the user of alloy steels and sheets.

Other Agathon Products

High Finish Sheets
Blue Annealed Sheets
Black Sheets
Galvanized Sheets
Terne-coated Sheets
Hot Rolled Strips
Toncan Metal
Enduro Stainless

Central Alloy Steel Corporation, Massillon, Ohio

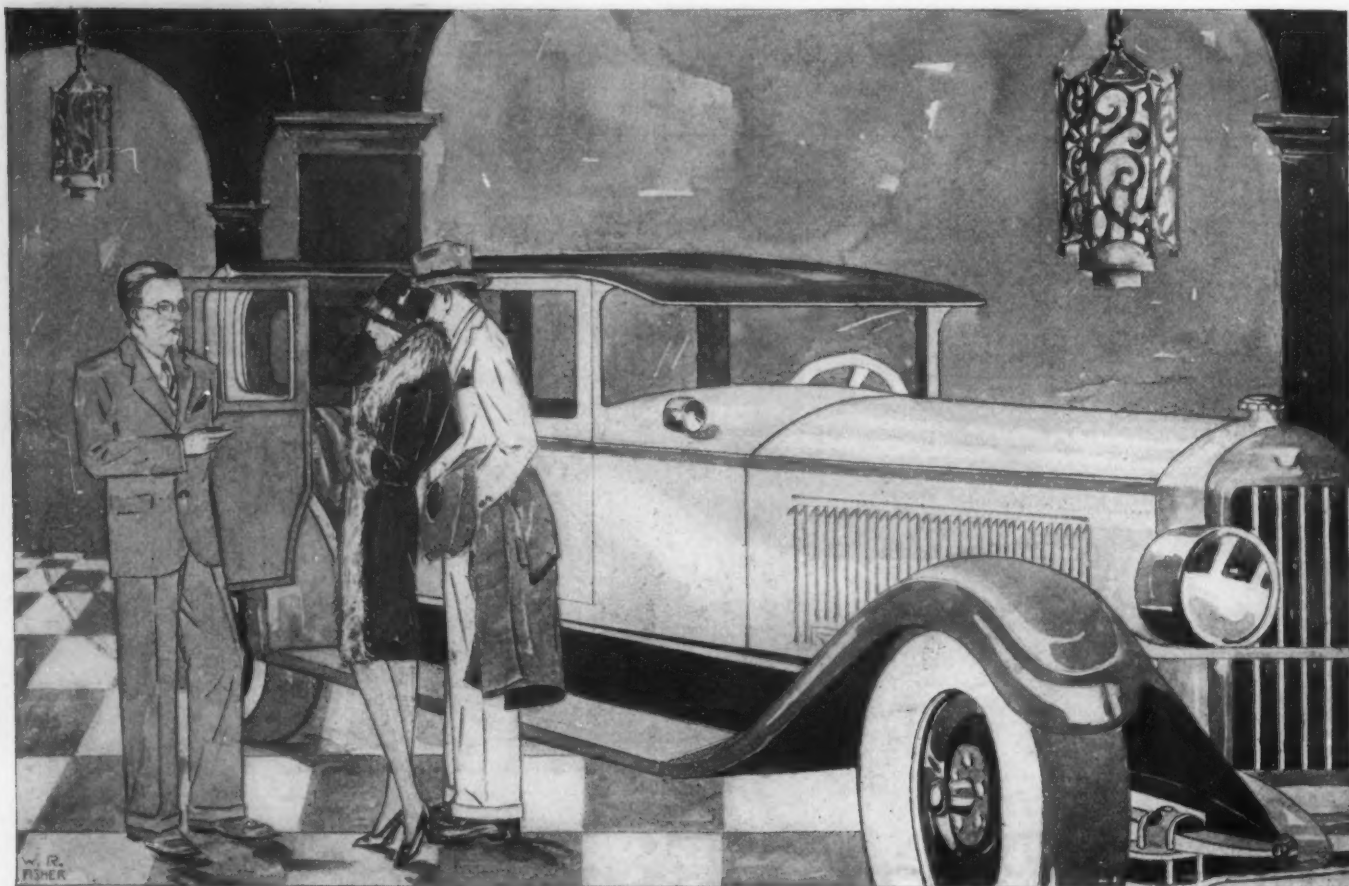
CLEVELAND
SYRACUSE

DETROIT
PHILADELPHIA

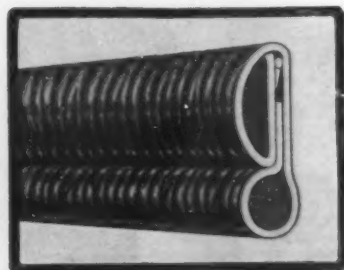
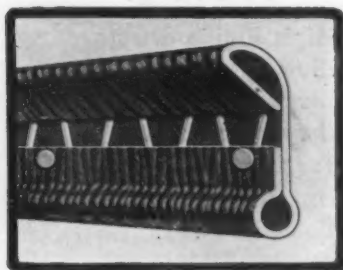
CHICAGO
LOS ANGELES

NEW YORK
TULSA

ALLOY STEEL



The Dotted Line



IT IS APPEARANCE as well as mechanical perfection that finally clinches the sale. Motor car refinement and distinctive appearance in upholstery and trimming are obtained by many of the leading car manufacturers through the use of Carter WIRE ON products.

Carter bindings have kept pace with the the motor car industry, representing the latest developments and highest quality trimming materials for every purpose.

Carter WIRE ON Products are easily and quickly applied, use less time than other methods, and positively eliminate the use of glue or paste at the time of their application, giving a neat, attractive and quality job at a minimum cost.

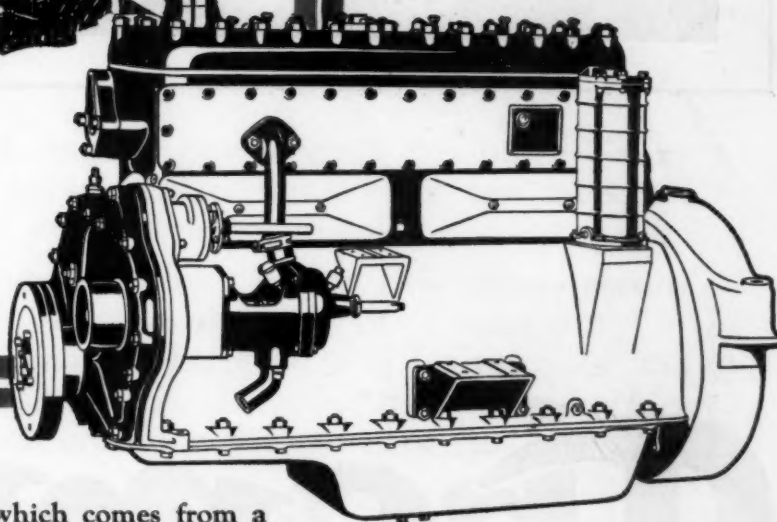
"There's a Carter Product for Every Finishing Purpose"

The Geo. R. Carter Co.
Connersville, Ind.
WIRE ON PRODUCTS

U.S. Patent, Aug. 16, 1921; Canada Patent July 25, 1922. Additional and Foreign Patents Pending



A Generation of Specialization



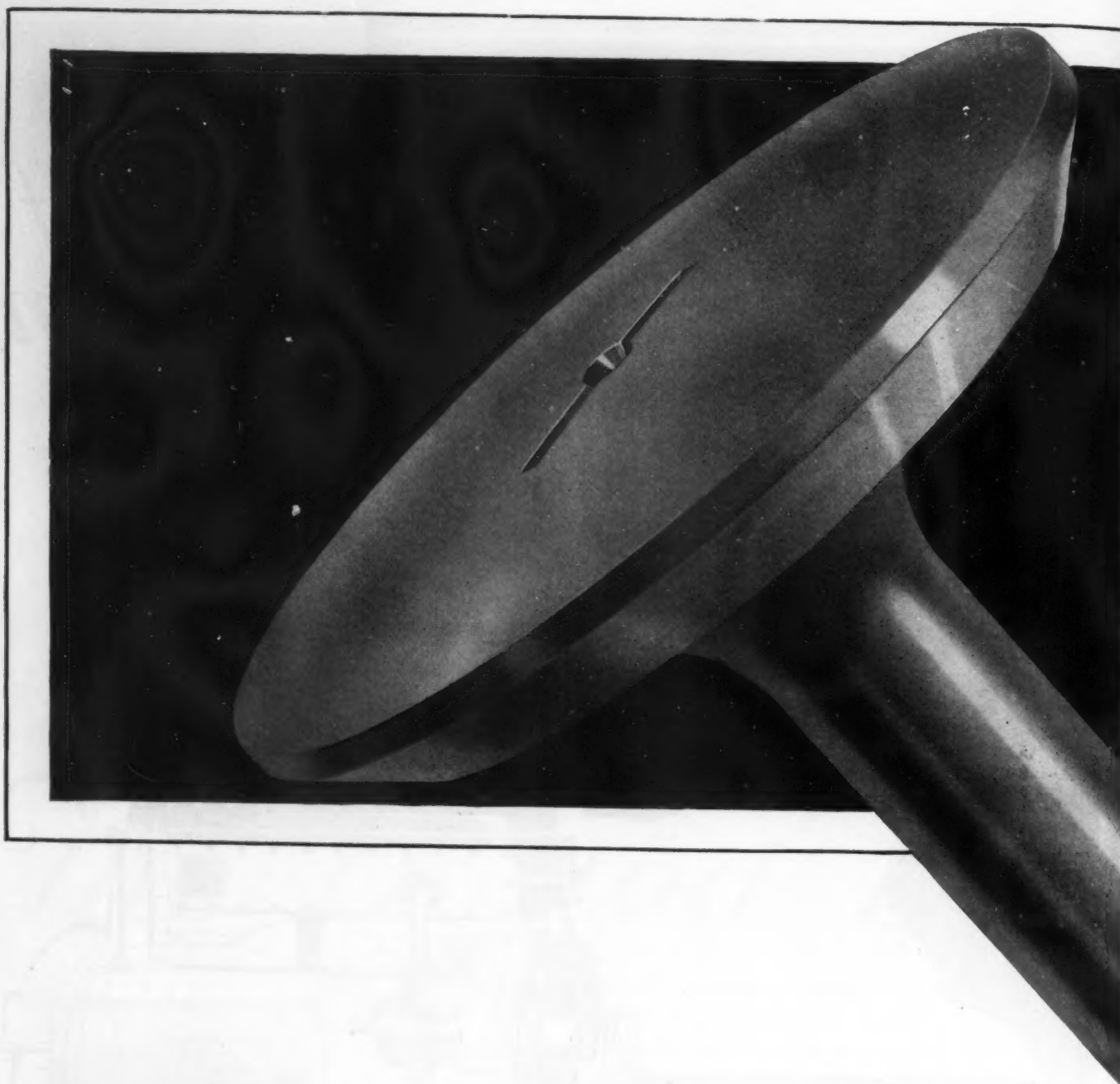
THE invaluable experience which comes from a generation of specialization cannot be duplicated by the efforts of a few years.

Continental Motors are the product of 26 years of concentration in building internal combustion engines. This experience is reflected in each of the 2,750,000 Continental Motors in use today.

CONTINENTAL MOTORS CORPORATION
Offices: Detroit, Mich., U. S. A. Factories: Detroit and Muskegon
The Largest Exclusive Motor Manufacturer in the World

Machining Continental cam shafts. Volume production is linked with quality workmanship.

Continental Motors



Thompson Valves

Creator of Good Will

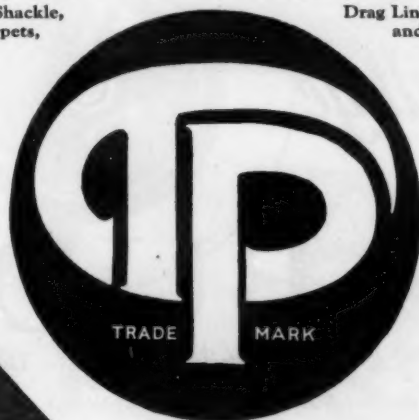
SUSTAINED engine power and flexibility—very infrequent valve replacements—far less need of carbon removal and valve grinding!

The car owner may not know that these results are due to the heat resistance of Thompson "S" Valves, but they increase his good will for your car and your engine just the same. In selecting your source of supply for valves, consider the effect of this good will on repeat business.

THOMPSON PRODUCTS, INCORPORATED
General Offices: Cleveland, Ohio, U. S. A. :: Factories: CLEVELAND and DETROIT

Thompson Valves, King, Shackle,
and Tie-Rod Bolts, Tappets,

Drag Links, Tie Rods, Starting Cranks,
and Brake-Rod Assemblies.





We asked Mr. Macauley.... ...he said "Ask the man who owns one!"

ALVAN MACAULEY is President of the Packard Motor Car Company . . . Last March he made Budd-Michelin Wheels standard equipment on all models of the Packard, both Six and Eight. We wanted to know what Mr. Macauley thought of them now, after six months experience, and so we asked him . . . "We put Packard on Budd-Michelins" said Mr. Macauley, "because we firmly believed they were the finest wheels for the finest car in America. Now we know it. Just . . . ask the man who owns one!"

We did. Hundreds of them. People who, in almost every instance, had also owned cars with wooden wheels. We asked them whether their experience made them prefer steel wheels (Budd-Michelin) or wood—and why?

Three out of every four persons interviewed endorsed the Budd-Michelin Wheel equipment with specific comments explaining their preference. Here are a few quotations from the actual replies.

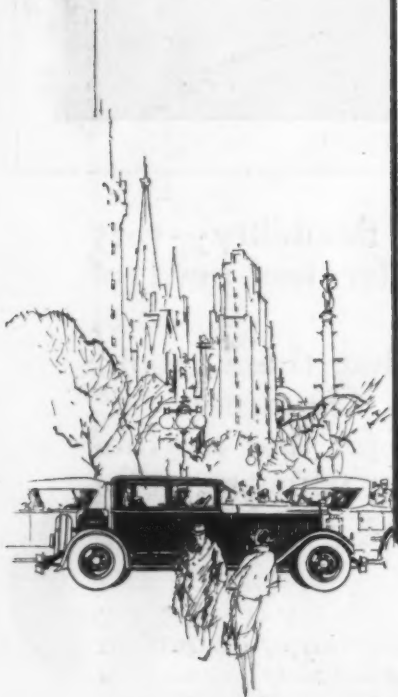
New York—"I prefer steel wheels by all means because of their better looks, their greater strength and the ease of cleaning."

California—"Brakes more accessible, wheels far easier to clean, they look better and are much safer. They, too, have an extra wheel."

Colorado—"In wet weather my brakes remain more dry and efficient with steel wheels."

New Jersey—"My car skidded. If I had had wood wheels I could not have continued my trip but the disc was just bent and easily reshaped. A wood wheel would have crushed."

And so runs the story of Budd-Michelin preference based on actual experience. Experience that has made Packard owners—as critical and discriminating a group as there is in all motordom—truly glad to swell the chorus of: "Good-bye, buggy wheels!"



"Goodbye



buggy wheels"

BUDD

Philadelphia Detroit

Also makers of Budd Interchangeable Wire Wheels which fit the same hub as Budd-Michelin All-Steel Wheels.

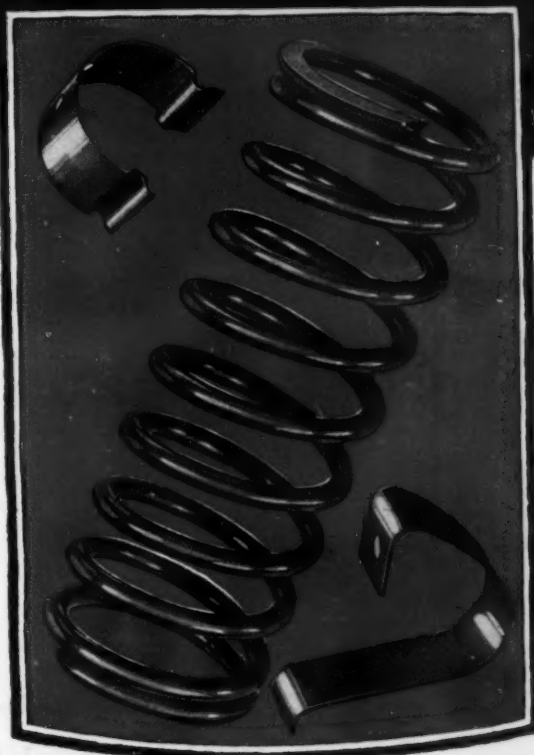


THE almost miraculous development of the Radio is no more amazing in its field than has been the perfecting of the special machinery for the scientific heat treatment of Cleveland Wire Springs.

Also manufacturers of
Steel Shop Barrels, Tote
Boxes, Steel Shelving,
Steel Stools, Steel Waste
Cans and Specialties.

THE CLEVELAND WIRE SPRING CO.
Main Office and Factory, Cleveland, Ohio

Branches:
CHICAGO, Machinery Hall DETROIT, Garfield Bldg.



CLEVELAND

COILED AND FLAT SPRINGS

WIRE FORMS OF ALL KINDS

CUSHIONS OF AIR

that absorb brutal road shocks

and prevent destructive twisting and wrenching of frame



NOTE the two illustrations. Figure 1 pictures what happens to the chassis of a truck not equipped with Gruss Air Springs.

Mark how the steel springs alone must bear the shock of road conditions. See how this results in throwing the Chassis to one side. Consider the damage and cost resulting from this wrenching and twisting of the frame — the consequent shifting of the load.

Now look at Figure 2. Note how the chassis remains level — how the shock and uneven road conditions are absorbed by the air cushions in Gruss Air Springs.

Our literature explains fully how Gruss Air Springs accomplish this: Why air springs are saving thousands of dollars yearly for truck and bus operators throughout America and in many European countries.

Shall we send you complete details?

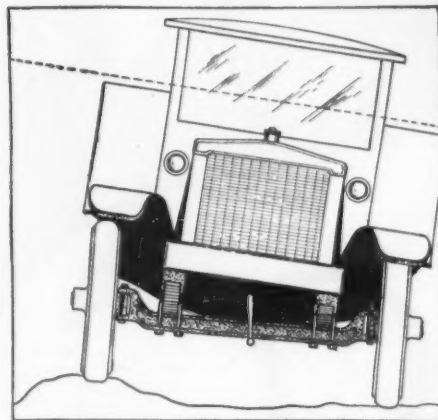


Figure 1 illustrating how chassis of truck not equipped with air springs is wrenching and twisted.

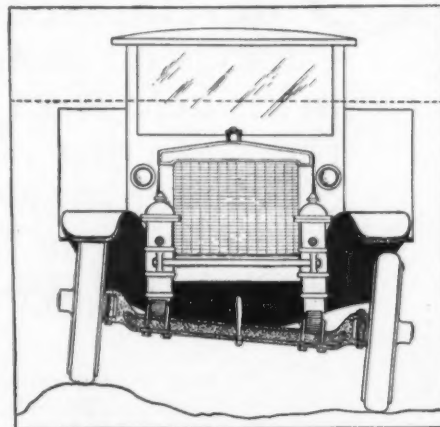


Figure 2, illustrating how air springs absorb the uneven road conditions and prevent wrenching and twisting of frame.

THE CLEVELAND PNEUMATIC TOOL CO.
Cleveland, Ohio

GRUSS AIR SPRINGS

for Trucks, Buses
Passenger Cars ~





VIOLENT and rapid changes of temperature, ranging from one extreme to the other, will not harm the softly glowing beauty of an Arcozon finish. From heated garage to severe blasts of coldest winter leaves its silken luster undimmed.

Manufacturers will also be interested in Arcozon's ease and economy of operation. May our technical department supply you with details?

THE ARCO COMPANY, CLEVELAND, OHIO
 Paints • Varnishes • Enamels • Lacquers (38)

SPRAYS ON

ARCOZON

STAYS ON

THE ARCO PYROXYLIN LACQUER SYSTEM

"The Right Bearing"



for Every Car"

The Right Bearings

Here at the plant of the Bearings Company of America, we do more than just "make bearings." The actual manufacturing processes are only a part of our business.

We take it as our responsibility to design and make the **Right Bearings** for every company that places an order with us. Our experienced Engineering staff studies the requirements of each automobile and determines just what the actual loads will be. The Bearings are then designed to carry those loads with an ample margin of safety.

We have developed the manufacturing processes to a high degree of perfection. When you place an order for a thousand or a hundred thousand B. C. A. Bearings, you can be certain that every one will be uniform in dimensions and strength.

Let us study your Bearings problems—it is probable that you can use B. C. A. Bearings to advantage.

Detroit (Michigan) Office: 1012 Ford Bldg.

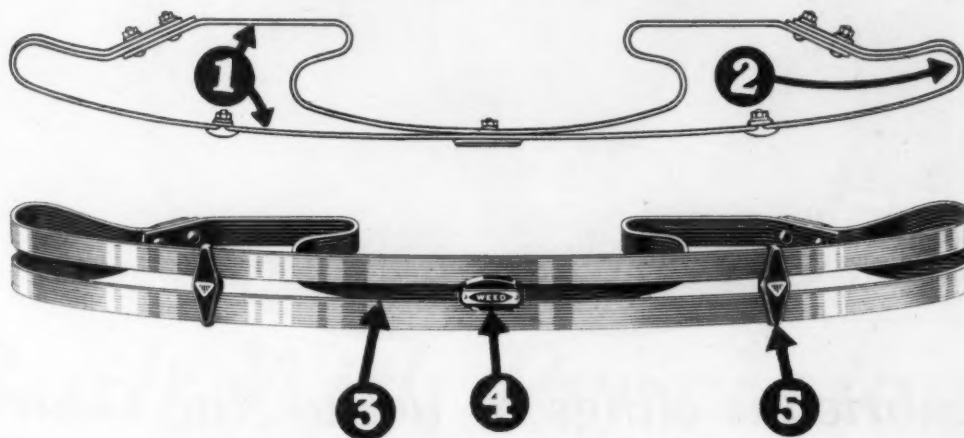
Angular
Contact
Radial
Bearing



THE BEARINGS COMPANY of AMERICA
LANCASTER, PA.

WEED BUMPERS

are correct in design
—to the smallest detail



1. Full shock space

Full shock space with spring steel selected of the grade best suited for bumpers, gives utmost bumper protection.

2. Loop-shaped ends

Loop-shaped ends—light enough to bend under impact, and heavy enough to withstand terrific shocks without breaking.

3. Re-enforcing

Rear bar overlaps front bar opening. This gives double re-enforcing and added strength for both rear and front bars. WEED front bars will not spread apart when hit. Both bars act together to resist shocks.

4. Emblems

Name plates and emblems are of nickel-plated brass.

5. Clamps

Good malleable, with lips between bars and over top and bottom to prevent spreading. Clamps are made heavy to perform their work, and shaped to prevent catching onto objects.

Besides mechanical features, which are superior, WEED Bumpers are beautiful—they add to the appearance of your car. Write for literature showing the types of WEED Bumpers best suited for your product. You may want to recommend them.

AMERICAN CHAIN COMPANY, Inc.
Bridgeport, Connecticut

In Canada: Dominion Chain Company, Limited, Niagara Falls, Ontario

District Sales Offices:

Boston, Chicago, New York, Philadelphia, Pittsburgh, San Francisco

Made by the manufacturers of Weed Chains and Weed Levelizers





Lubricant clings to a Bakelite Gear but is not absorbed

Bakelite laminated gears may be operated continuously in a bath of oil with no chance of any dimension being altered through absorption.

Bakelite laminated is also immune to injury through chemical action of lubricants; is unharmed by contact with gasoline, fumes or water, and unaffected by extremes of heat and cold.

For these reasons, and because of its great toughness and strength, Bakelite laminated has become the standard material for the non-metallic silencing gear of timing gear trains.

Bakelite laminated gears and gear blanks are obtainable under any of the following names:

FORMICA
Made from Anhydrous Bakelite Resin
SHEETS TUBES RODS

Fibroc contex

Textolite CELORON Micarta

BAKELITE CORPORATION

247 Park Avenue, New York, N. Y.

Chicago Office, 636 W. 22nd Street

BAKELITE CORPORATION OF CANADA, Limited, 163 Dufferin Street, Toronto, Ont.

BAKELITE

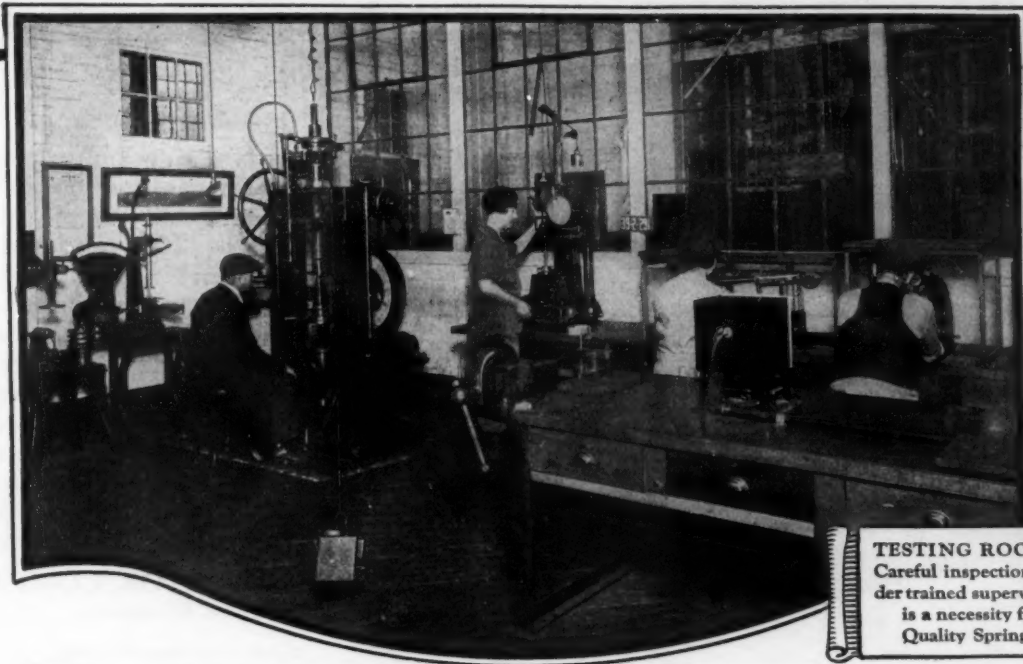
REGISTERED

U. S. PAT. OFF.



THE MATERIAL OF A THOUSAND USES

The registered Trade Mark and Symbol shown above may be used only on products made from materials manufactured by Bakelite Corporation. Under the capital "B" is the numerical sign for infinity, or unlimited quantity. It symbolizes the infinite number of present and future uses of Bakelite Corporation's products.



TESTING ROOM—
Careful inspection under
trained supervision
is a necessity for
Quality Springs.

Built With Precision For Dependable Performance

Dependable performance is assured in Quality Springs through proper coordination of design, materials and craftsmanship.

Back of every Quality Spring there lies a century of experience—and a reputation built by dependable performance.

Quality Springs

AMERICAN STEEL & WIRE COMPANY

Sales Offices

Chicago New York Boston Cleveland Worcester Philadelphia Pittsburgh Buffalo Detroit Cincinnati Baltimore
Wilkes-Barre St. Louis Kansas City St. Paul Oklahoma City Birmingham Memphis Dallas Atlanta Denver Salt Lake City

Export Representative: U. S. Steel Products Co., New York

Pacific Coast Representative: U. S. Steel Products Company, San Francisco, Los Angeles, Portland, Seattle



One of the newest developments in railroading, the Gas-Electric coach, used by the C. & N. W. Ry. Built by the Electro-Motive Company, Cleveland. A 225 h. p. 6-cylinder engine, cooled by a Perfex Radiator, drives the generator which supplies the operating power.

For every special cooling problem as well as standard requirements our engineering staff of cooling specialists offers seasoned, practical experience in radiator design.

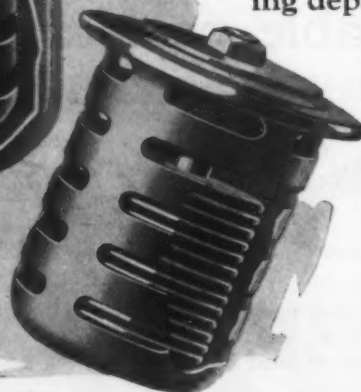
It's worth remembering that of all exhibitors showing gas powered machines at the last Chicago Road Show 90% used Perfex Radiators

WHEN a new or unusual job for gasoline motors is on the boards, one of the first questions is, "How about the cooling system?" Manufacturers welcome the practical information acquired by and recorded in our engineering department. In the course of 16 years experience, operating conditions of every sort have been encountered and overcome by applying scientific knowledge to practical design.

RACINE RADIATOR COMPANY
Racine, Wisconsin

Pacific Coast Representative
ENGINEERING & SALES CO.
24 California Street, San Francisco, Calif.

PERFEX
THE PERFECT RADIATOR



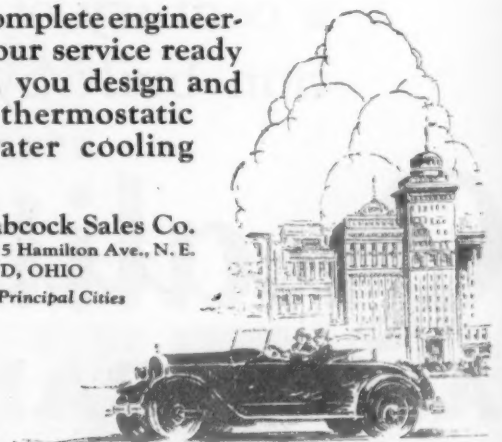
One of Several

BISHOP & BABCOCK standardized thermostat designs suitable for built in or hose line installations.

Several hundred thousand instruments in actual service testify to the efficiency and serviceability of these units.

An experienced and complete engineering department is at your service ready to discuss with you design and production of thermostatic control for water cooling systems.

The Bishop & Babcock Sales Co.
General Offices: 4901-4915 Hamilton Ave., N. E.
CLEVELAND, OHIO
Branch Offices in Principal Cities



BISHOP & BABCOCK
TEMPERATURE REGULATION

Let

TRADE *Pantasote* MARK

Ruggedness work for You!

Do not confuse Pantasote with ordinary "imitation leathers." It is made by a process basically different from any other leather substitute. To that fact is due its extraordinary wearing qualities.

Fire resistant, washable, it will not crack or rot. Pantasote withstands the hardest wear and abuse.

The finest of colors and grains can be had in Pantasote, to blend with any bus finish.

This book

containing all the beautiful new colors and finishes will help you choose a material beautiful as well as durable.



**Send
for it
TODAY**

The PANTASOTE Co. Inc

**250 Park Avenue
NEW YORK CITY**

THE PANTASOTE CO., INC.

250 Park Ave.

New York City

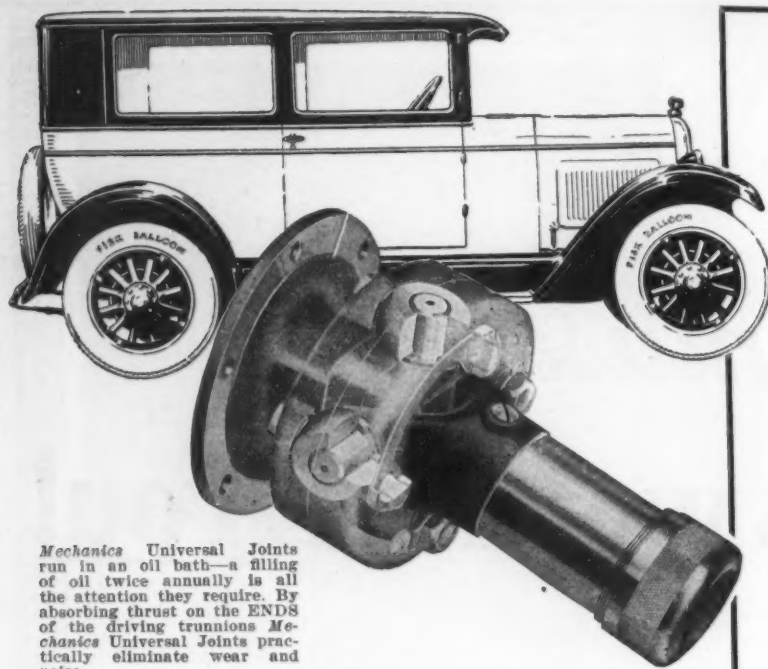
Gentlemen:

Send me the new Pantasote Sample Book.

Name

Firm

Address



Mechanics Universal Joints run in an oil bath—a filling of oil twice annually is all the attention they require. By absorbing thrust on the ENDS of the driving trunnions *Mechanics Universal Joints* practically eliminate wear and noise.

Willys-Overland

Adds the "Whippet" to
Its Line of Cars Using
**MECHANICS
UNIVERSAL JOINTS**

Willys-Overland have standardized on *Mechanics Universal Joints*—using them exclusively in Willys-Knights and Overland Sixes.

As a final proof of their utter confidence in *Mechanics Universal Joints*, Overland once more compliments *Mechanics* by making them standard in the new "Whippet."

The compliment is not only directed at the sturdy qualities of the *Mechanics Universal Joint*, but also at our immense manufacturing facilities which enable us to keep abreast of a production schedule as huge as Overland's.

MECHANICS MACHINE COMPANY

ROCKFORD

ILLINOIS

Sales Representatives

C. A. S. ENGINEERING CO., 4222 Woodward Avenue,
DETROIT

UNIFORM RELIABILITY

It is a constant and ever-increasing satisfaction to Firestone users—that absolute dependability—that consistently longer mileage they enjoy with Gum-Dipped Tires!

This extra value is explained by the Extra Firestone Process of Gum-Dipping. This so thoroughly insulates every fiber of every cord in rubber, that internal friction (with its destructive heat) is practically eliminated. Naturally, the tires deliver more miles in greater safety and comfort.



MOST MILES PER DOLLAR

Firestone

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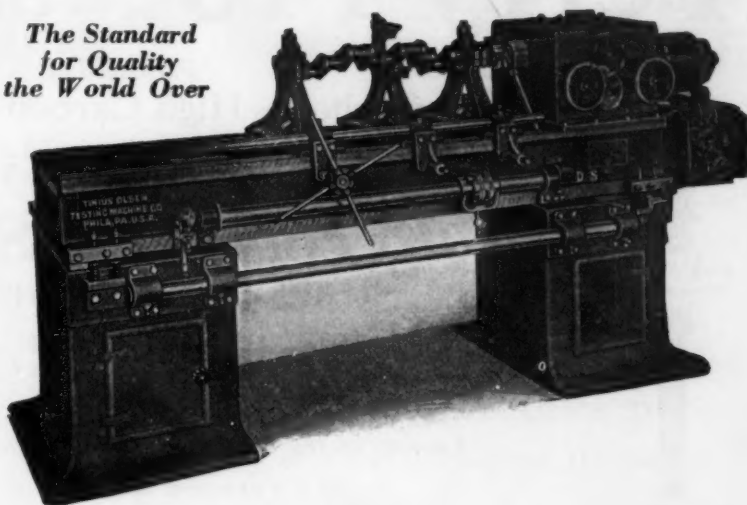
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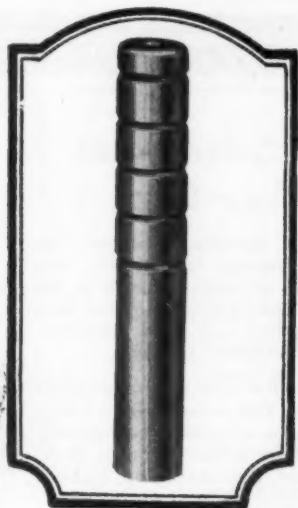
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All these—each contributing to higher stamping cost—can be eliminated, or minimized by *Danly Die Sets*.

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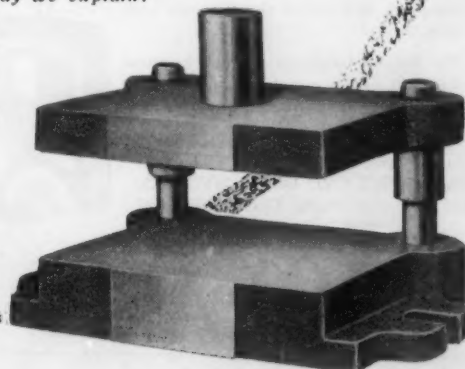
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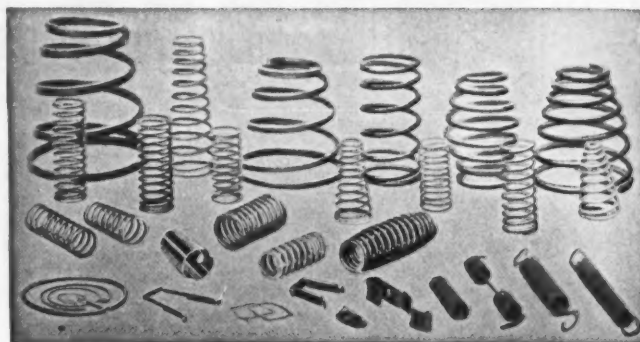
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Deck Seat Arm Rest Irons

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Deck Seat Arm Rest Iron
Part No. 23

As shown in the sketch, one end of arm rest is fastened to the deck lid. As the lid is lifted the arm opens with the seat and is locked into position by a ball catch. The arm is held rigidly in this position while the seat is in use. By again releasing the ball catch the arm is quickly folded back out of the way by closing the deck lid.

The arm made of Eberhard Malleable is strong but light in weight. Supplied in rights and lefts, two arms to a set. Nicely finished in bright nickle on copper plate.

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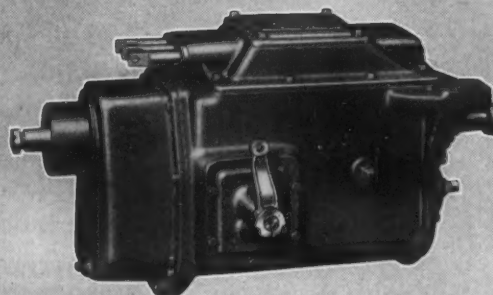
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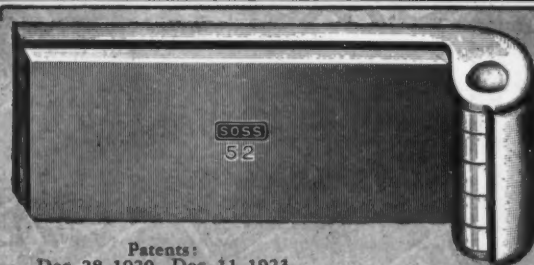
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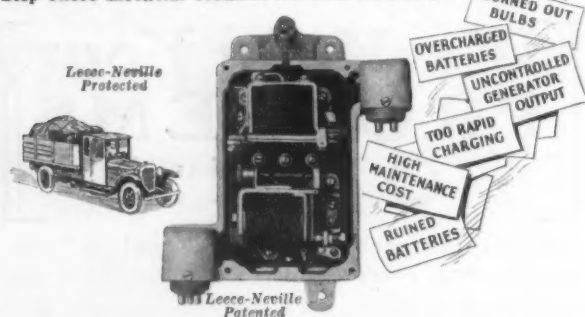
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Voltage Regulation Nips Trouble in the Bud

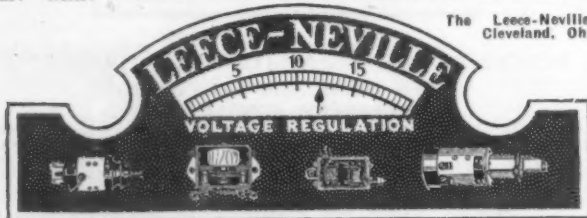
Burning up of a generator, or breaking down of the plates in the battery, burnt out lights, because someone replaced a fuse with a piece of wire, because overcharging too rapidly evaporated the water in the cells, or because corroded terminals invited a dangerous voltage rise . . . these cannot occur to the electrical system controlled by Leece-Neville Regulated Equipment. Voltage Regulation makes practically all electrical troubles unnecessary. For it makes power in-out proportional to power out-put. Leece-Neville equipment reduces electric service and expense all along the line. The life of the battery, generator and light bulbs is greatly prolonged. When such an organization as the Cleveland Railway Co. specify Leece-Neville for their Buses, it suggests that others may profit by investigating. Have you the latest important facts about Leece-Neville Systems? Write!

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10. Motor coaches fitted with Leece-Neville voltage regulated generators provide passengers with satisfactory illumination and safe transportation.

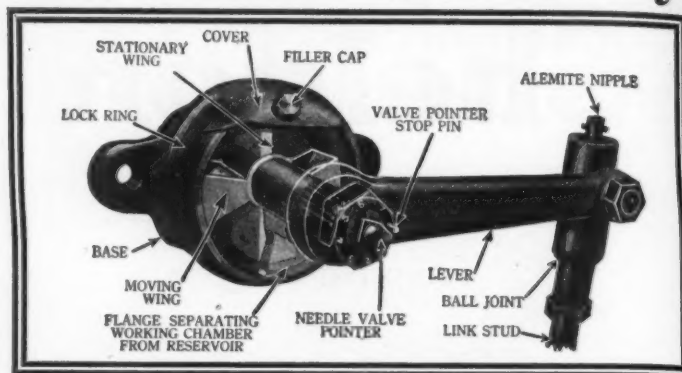
Leece-Neville Patented

Voltage Regulation Minimizes
Electric Maintenance

The Leece-Neville Co.,
Cleveland, Ohio



This tells the story



ABOVE is a detail illustration of the Houdaille hydraulic double-acting Shock Absorber with cover of hydraulic chamber partially removed so as to expose interior to view.

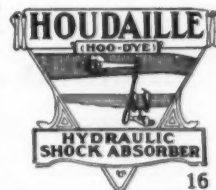
The hydraulic chamber section is bolted to the chassis frame—the perpendicular arm (only partially pictured) firmly grasps the springs. Action is positive and thorough under all conditions.

Made of molybdenum steel throughout and more finely machined than any part of any car, the Houdaille has no springs, straps or cables—is absolutely water and dust tight and will outwear the car.

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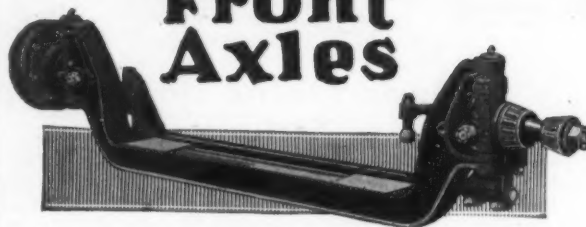
Houde Engineering Corporation
189 Winchester Ave., Buffalo, N. Y.

Manufacturers also of the famous
SCULLY QUALITY SPRING PROTECTORS
"that keep your springs like new"



16

Shuler Front Axles



**For: TRUCKS, MOTOR BUSES,
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A sample *Shuler Front Axle*—then a test of your own, unhampered, under your own conditions, is the best salesman we have.

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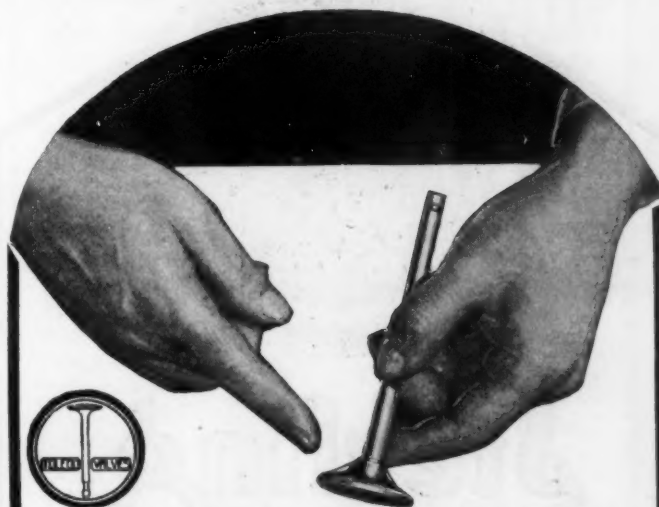
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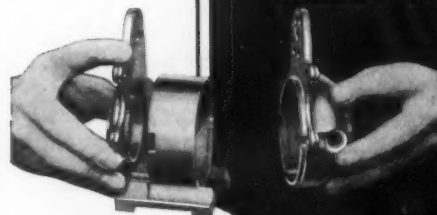
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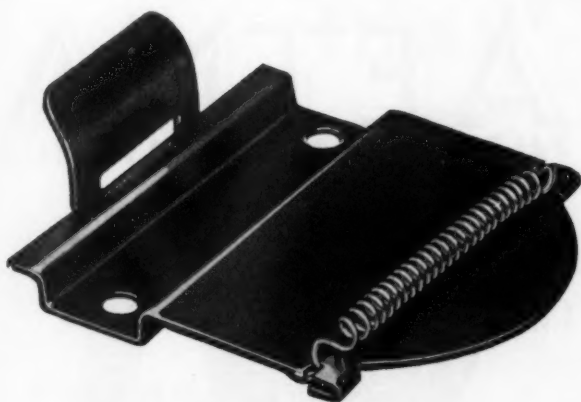
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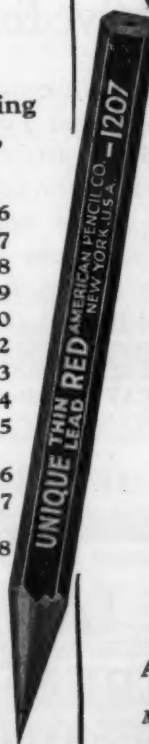
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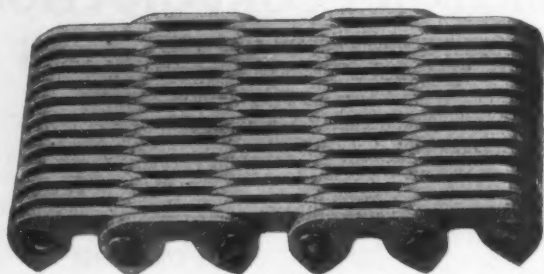
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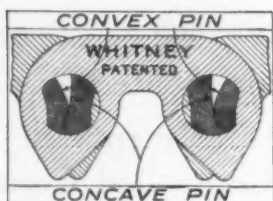
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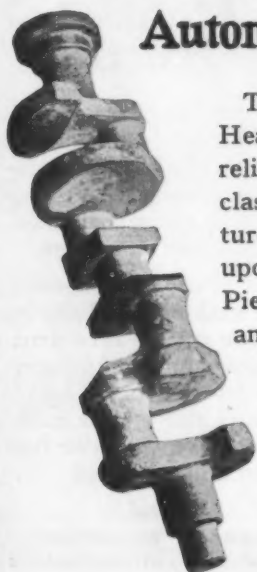
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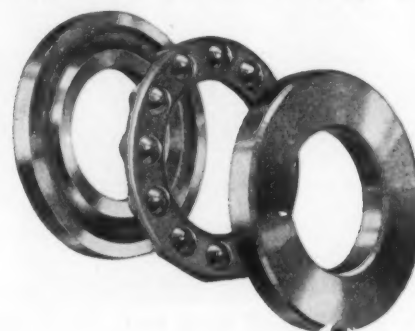
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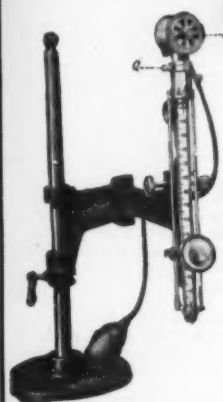
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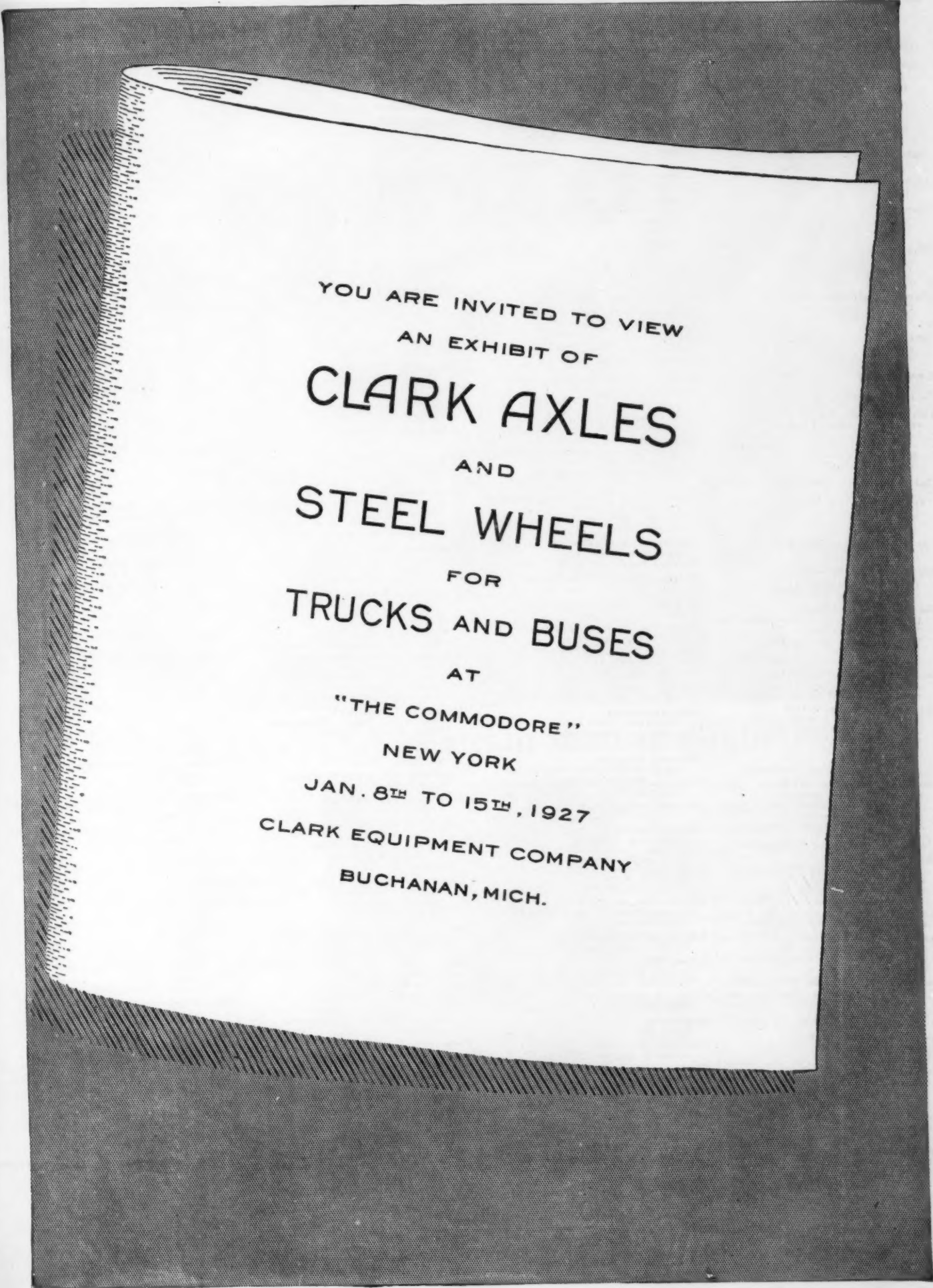
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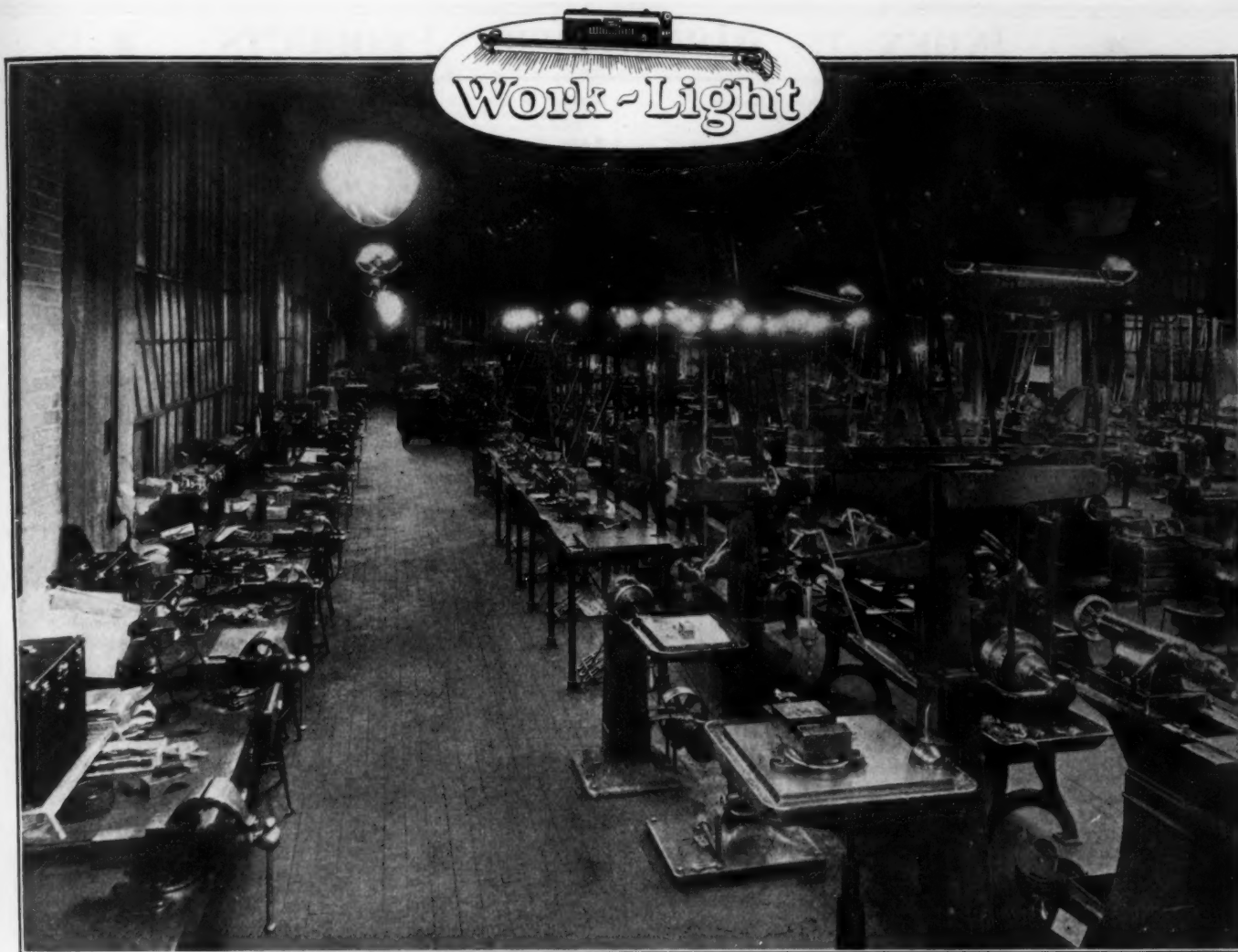
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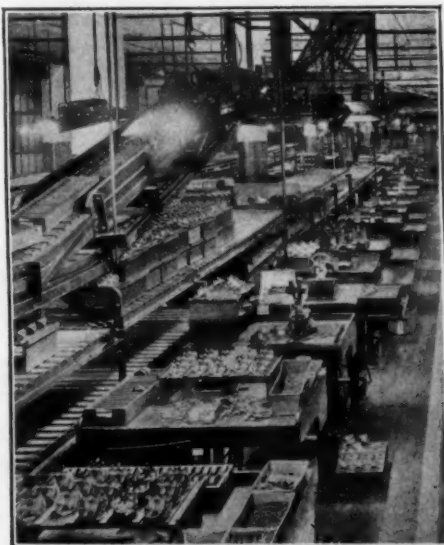
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“—with even less strain than daylight”

And on some of the operations about which the A C Spark Plug Company is most particular, it uses Cooper Hewitt Work-Light “at all times, as we find that the light from the windows, even on a clear day, changes in intensity and casts shadows on the work that results in poorer inspection than we get with the artificial light,” says Electrical Engineer Kelly.

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“The work is not at all ordinary. It is very close inspection and assembly of the jewels and speed cups for our speedometers,” Mr. Kelly adds. “Cooper Hewitt gives us best satisfaction because it brings out defects on fine and highly polished surfaces with less eye-strain than daylight.”



ments. Expert manufacture of spark plugs and speedometers enforces accuracy within unusually narrow limits.

Work-Light, seen in the tool-room and over inspection and assembly* tables in such a plant, once more brings home the story of clear seeing power, uniform 24 hours every day, which every plant needs under present conditions. A trial installation incurs no obligation. Cooper Hewitt Electric Co., 110 River Street, Hoboken, N. J.

COOPER HEWITT

BETTER THAN DAYLIGHT



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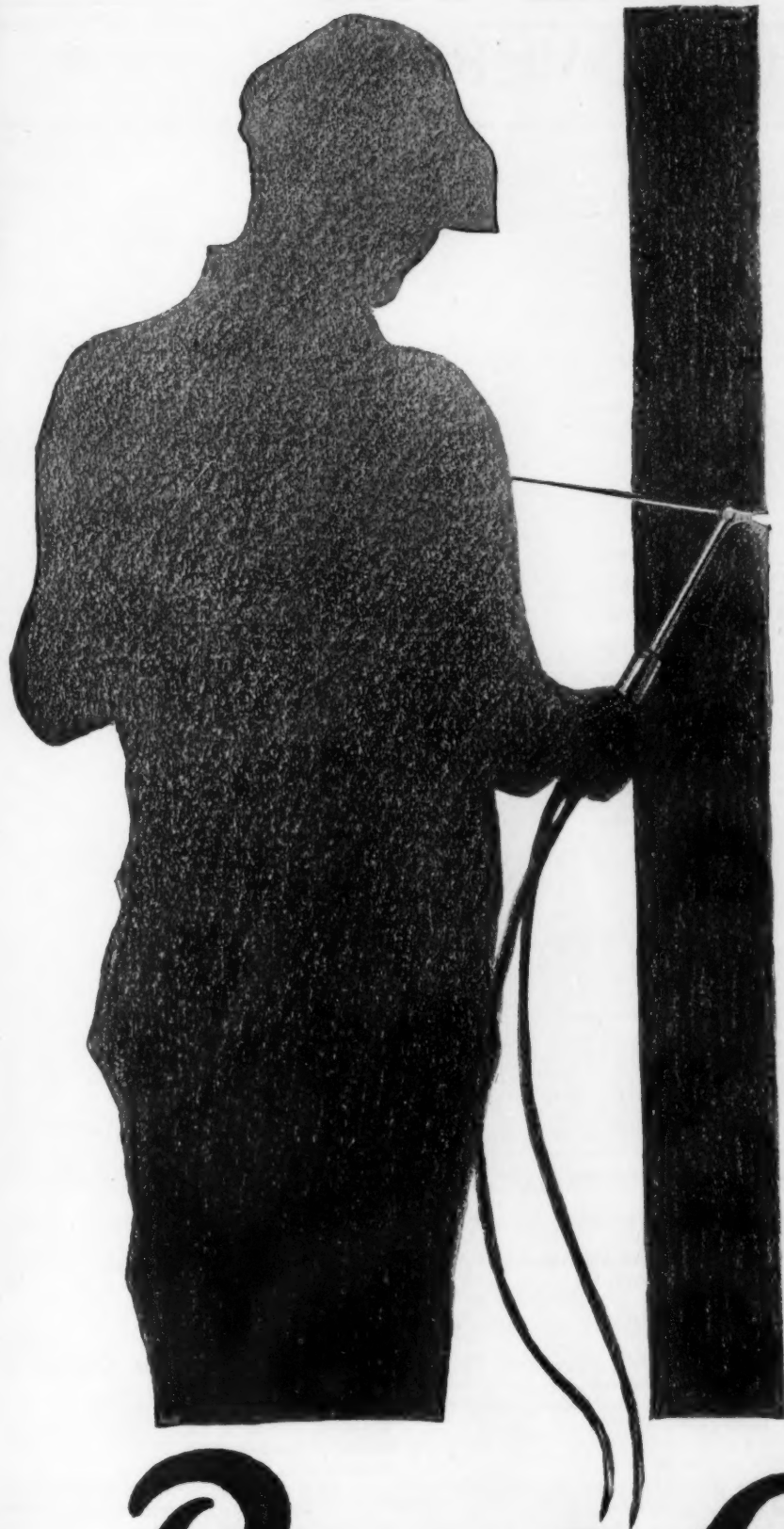
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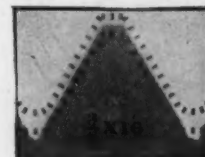
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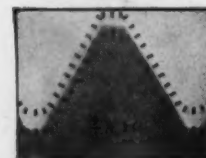
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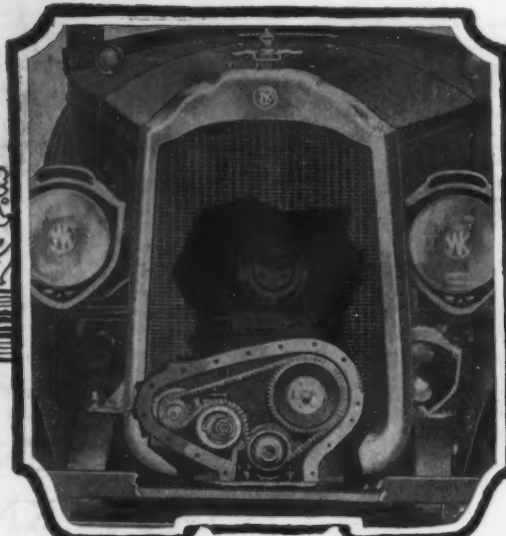


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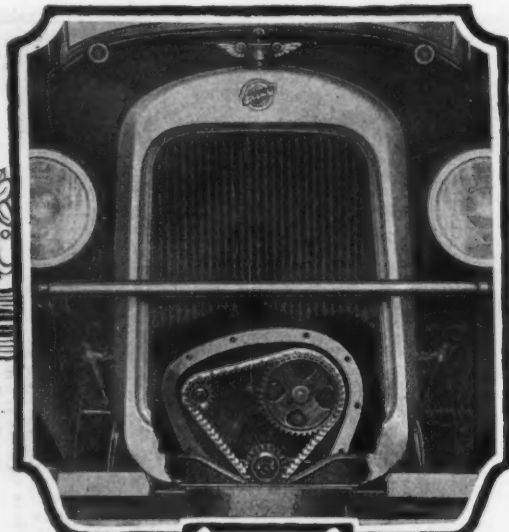


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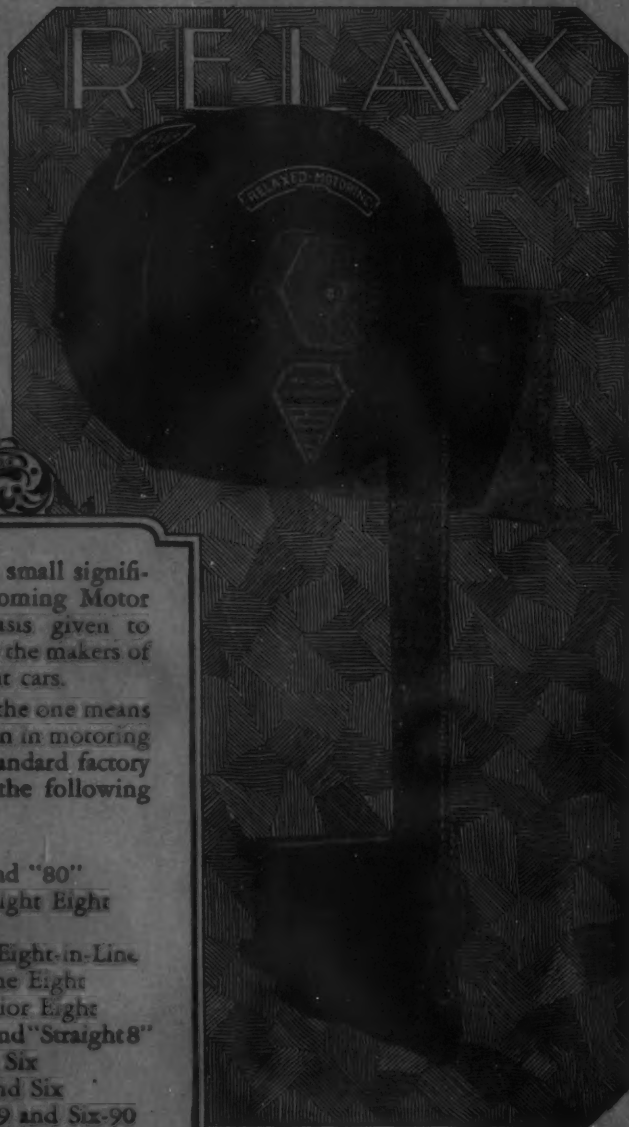
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